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R. F. SUSTAINED MAGNETOPLASMAS IN ARGON, HELIUM, AND NITROGEN

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ABSTRACT

Four mechanisms thought to be important in understanding plasma production in microwave plamsa sources are: 1.) collisional phase mixing, 2.) single particle cyclotron resonance, 3.) bounded plasma resonance, and 4.) standing Bernstein wave resonance. By examining the luminosity of the plasma as the magnetic field is swept, one can identify the mechanisms operating for a particular set of plasma conditions. In this paper we report observations carried out on three gases used in the MACOB plasma source at pressures of 0.1 to 100 mTorr and for magnetic fields of from 0 to 3 kG. Regions on the B vs. p diagram for each of the gases have been identified where one or more of the basic mechanisms is observed to be important. Mechanisms 1.) and 2.) appear to be able to account for the observed plasma densities. Process 3.) does not appear to be important for plasmas generated in a strong magnetic field gradient, and process 4.) appears to be operative but not required to explain the observed plasma densities.

INTRODUCTION

Many plasma sources (Lisitano, 1968; Lisitano, 1970; Aubert, 1971) make use of a microwave coupling structure located in a magnetic field to generate plasma. Usually the source will be found to operate over such a wide range of pressure and magnetic field that more than one physical mechanism is probably responsible for transferring energy from the r.f. field to the sustained plasma. If the pressure is sufficiently high, electron-neutral collisions will provide the phase mixing necessary for electrons to gain energy in the oscillating field. If the pressure is low, but the magnetic field is near the value necessary to produce single particle cyclotron resonance, we will observe excellent energy transfer, even though the electron-neutral collision frequency is low.

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If the plasma density is sufficiently high and if it is localized to a small region of space, one can observe bounded plasma resonances and resonances which have been attributed to the establishment of a standing Bernstein wave pattern across the plasma column, transverse to the magnetic field.

We have undertaken a parametric study of argon, helium, and nitrogen to determine the ranges of magnetic field B, and pressure p, over which these mechanisms can be observed in order to better determine which are fundamental to the plasma generation process.

I. APPARATUS

The measurements were carried out in the MACOB (MAgnetically Confined, Overdense, Bounded) plasma source (Sanders, 1972) Fig. 1, which makes use of a microwave cavity, located in the field gradient of a magnetic mirror confinement field. A 0.8 m x 0.016 m cylindrical quartz tube passes axially through a microwave cavity confining the plasma in the cavity to a cylindrical region having a radius small compared to the r.f. free space wavelength. One end of the tube passes through the stainless steel end plate of the main vacuum chamber.

The main pyrex vacuum chamber is 2.6 m long and 0.15 m in diameter and occupies most of the volume of the solenoidal magnetic field. The base pressure of the system is typically 10^{-7} Torr and the operating pressure is typically 0.1 to 100 mTorr. A vacion pump is used to maintain the base pressure and a mechanical rough pump with a molecular sieve trap is used to bring the pressure down to 0.1 mTorr. Pressure measurements for this work were made with two standard thermocouple gauges, one located near the pumping station and one in the gas manifold.

Power of up to 125 W at 2.45 GHz is coupled to the driver cavity by means of a large r.f., H-field probe. Plasma densities are measured by observing the frequency shift of the maximum r.f. signal transmitted through a second, fixed dimensional diagnostic cavity, located between the driver cavity and the main vacuum chamber. The r.f. signal is provided by a 10 mW 1.8 - 4.2 GHz sweeper.

The measurement of the different gas plasmas is carried out by filling the chamber with the gas under investigation, starting from a base pressure of 10^{-7} Torr up to the desired operating pressure. We do not pump on the system while the measurements are being made. The vacuum system is sufficiently free of leaks, that the pressure remains constant over the typical ten hour data run.

Magnetic field measurements are made with a Hall effect probe and complete field mapping measurements have been performed in the field region occupied by the cavities so that the field at any point within either cavity can be inferred from the indications of a gaussmeter probe mounted in a "standard position" along the outside of the driver cavity.

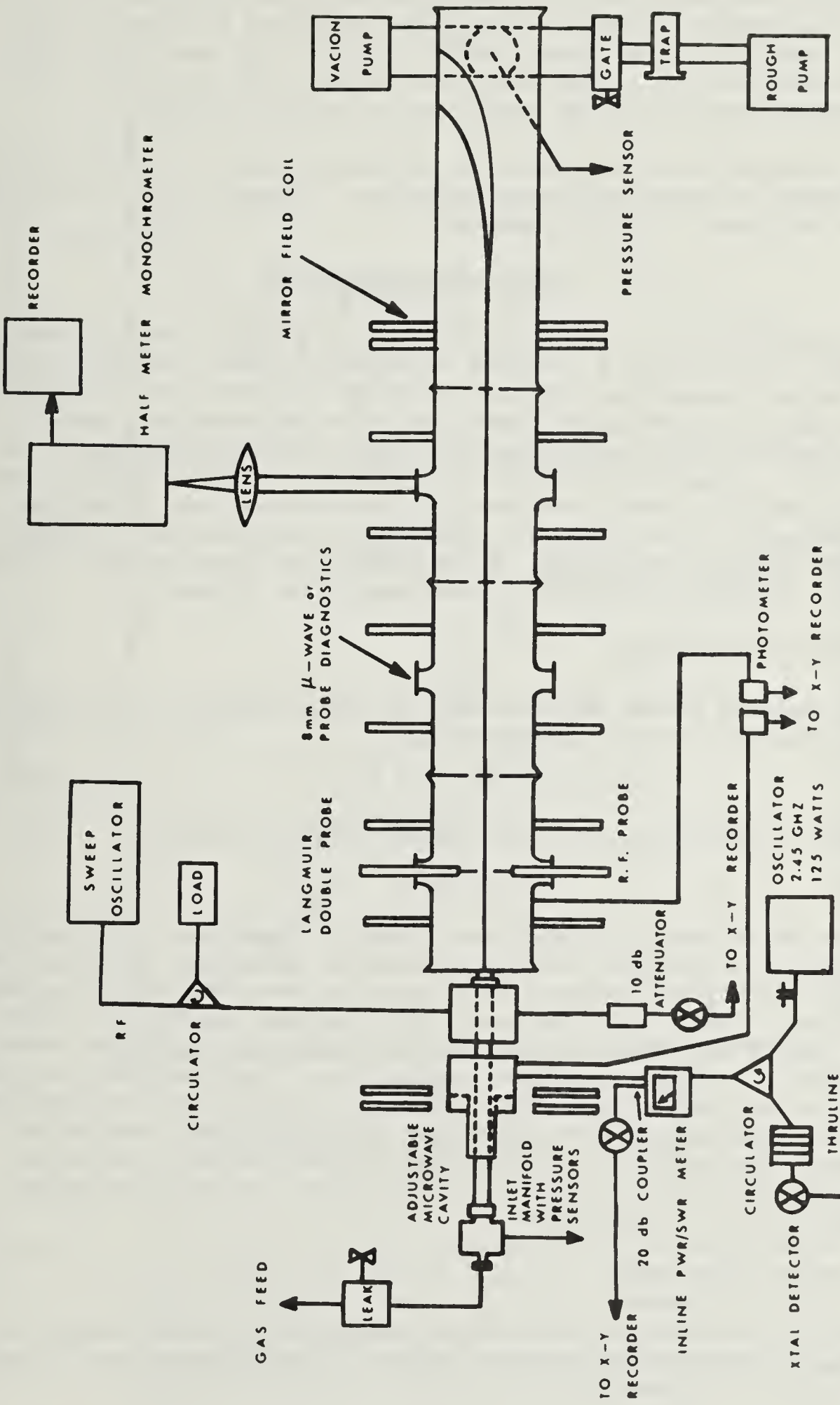

Figure 1. Principle components of the MACOB plasma source.

Plasmas have been created using the TE_{111}, TM_{011}, and TE_{211} modes of the driver cavity. The measurements cited in this paper are all for plasma generated using the TE_{111} mode excited by a large loop probe located in the cavity side wall. The modes are tuned by changing the length of the cavity. Frequency shifts of the TE_{111} and TM_{011} modes of the diagnostic cavity have been used to infer the density as the plasma passes from the driver cavity into the main chamber.

The luminosity of the plasma in the driver cavity and in the main vacuum chamber is measured with photometers. Plasma outside the driver cavity is referred to as the "tongue".

II. PLASMA CHARACTERIZATION

It has been shown (Messian and Vandenplas, 1969) that by observing the plasma luminosity as a function of magnetic field, one can identify bounded plasma resonances, and resonances at harmonics of the cyclotron frequency which indicate the presence of standing Bernstein waves. Previous work has dealt with the generation of these resonances in a uniform field. However, it is clear from Fig. 2 that the MACOB plasma luminosity exhibits these characteristic resonances even though the plasma generation takes place in a magnetic field gradient. We have used these observed resonances in the luminosity versus magnetic field data as one property by which to characterize the plasma.

BERNSTEIN WAVE RESONANCE

Well defined minima in recordings of the luminosity versus magnetic field for magnetic fields satisfying

$$\omega_c/\omega = n/m \qquad 1.)$$

with n and m integers and the electron cyclotron frequency

$$\omega_c = eB/m$$

with e the magnitude of the electron charge in Coulombs, m the mass of the electron in kilograms, and B the magnetic induction in Tesla, have been attributed to the presence of a standing Bernstein wave (Bernstein, 1958; Dreicer, 1965; Stone and Auer, 1965) pattern across the plasma column. Fig. 2 is a trace exhibiting the resonances at fields satisfying the conditions for Bernstein wave propagation. The dispersion relation for these waves indicates that they cannot be generated when condition 1.) is satisfied, but rather, depending upon the plasma temperature and density, for magnetic fields either slightly above or below the fields given by this condition. Thus we expect a minimum luminosity when condition 1.) is satisfied.

BOUNDED PLASMA RESONANCE

The internal eleetric field of a uniform, cylindrical dielectric rod having a dielectric constant κ, placed in a uniform electric field of magnitude E_o is given by:

$$E_i = 2E_o/(1 + \kappa) \qquad 2.)$$

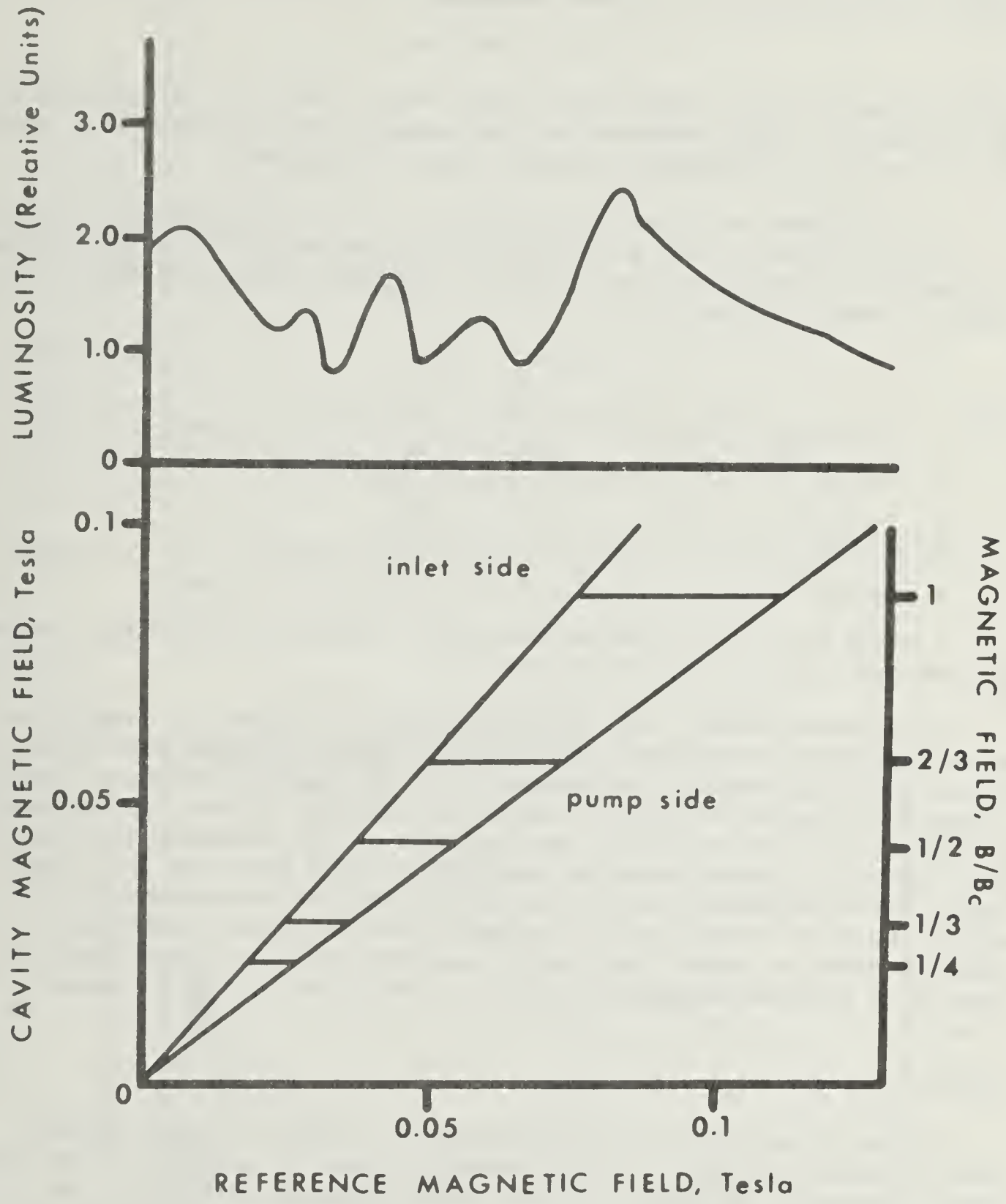

Figure 2. The minima in plasma luminosity occur when Bernstein wave generation is no longer possible, B/Bc = n/m. (Bc is the magnetic field at which cyclotron resonance takes place; n and m are integers.) Since the driver cavity is located in a field gradient, this condition can be satisfied for a range of reference field values.

For a plasma, κ can be less than zero and hence resonances are possible when $\kappa = -1$. In a cylindrical geometry the resonance occurs for $\omega = \omega_p/\sqrt{2}$ rather than at the plasma frequency,

$$\omega_p = Ne^2/m\varepsilon_o$$

with N = the electron density per cubic meter, and ε_o = the permitivity of free space. This resonance is the lowest order resonance of a series of multipolar, cylindrical, bounded plasma resonances.

For a plasma contained in a dielectric tube having an inner radius b, an outer radius c, and a dielectric constant $\kappa_t = \varepsilon_t/\varepsilon_o$, and located in a magnetic field, the condition for a bounded plasma resonance (Vandenplas, 1968) is given by

$$\omega_p^2/\omega^2 = \Omega_{\pm n} \qquad 3.)$$

with

$$\Omega_{\pm n} = (1 + \kappa_t|Q_n/P_n|)(1 \pm \beta) \qquad 4.)$$

$$P_n = \varepsilon_o(b^{-2n} - c^{-2n}) + \varepsilon_t(b^{-2n} + c^{-2n})$$

$$Q_n = \varepsilon_o(b^{-2n} + c^{-2n}) + \varepsilon_t(b^{-2n} + c^{-2n})$$

$$\beta = \omega_c/\omega$$

ω = the r.f. source radian frequency, and with n an integer defining the multiple order of the resonance.

If a steady state, r.f. discharge tends to adjust its density so as to maintain a resonance condition with the r.f. field (Leprince, 1971), one would expect the luminosity of the magnetoplasma, at fixed pressure and magnetic field, to have two possible values, corresponding to operation on either of the two branches of the resonance given by Equation 3.). Plasma operating conditions which give rise to a luminosity versus magnetic field trace exhibiting the characteristics of either resonance branch will be termed "bounded plasma conditions". Figure 3 shows an argon trace which suggests that the plasma might be fixed to a bounded plasma resonance, at least for $B < B_c/2$, where $B_c = m\omega/e$.

THE JET

At sufficiently high pressure and for magnetic fields greater than the cyclotron field, a high density plasma is observed in the main vacuum chamber. If conditions are chosen properly, milliwatts of r.f. can be observed far down the plasma column. Evidence of a parametric decay process (Chang, 1972) has been reported for helium and argon under jet conditions. The jet seems to correspond to the high density plasma produced by Lisitano (Lisitano, 1970) and suggested as a possible fusion plasma injection source. Fig. 4 indicates the luminosity characteristics recorded by a photometer looking into the driver cavity and by one looking at the tongue in the main chamber.

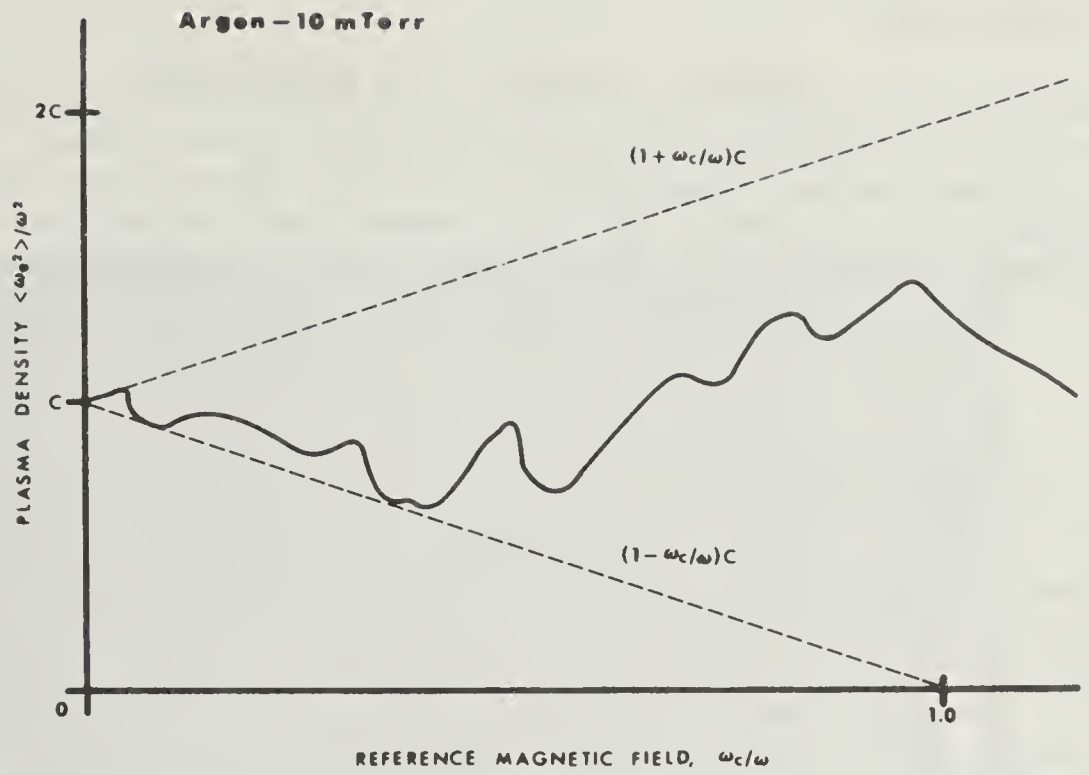

Figure 3. R.f. sustained argon plasmas appear to follow the lower branch of a cylindrical multipole resonance for low magnetic fields.

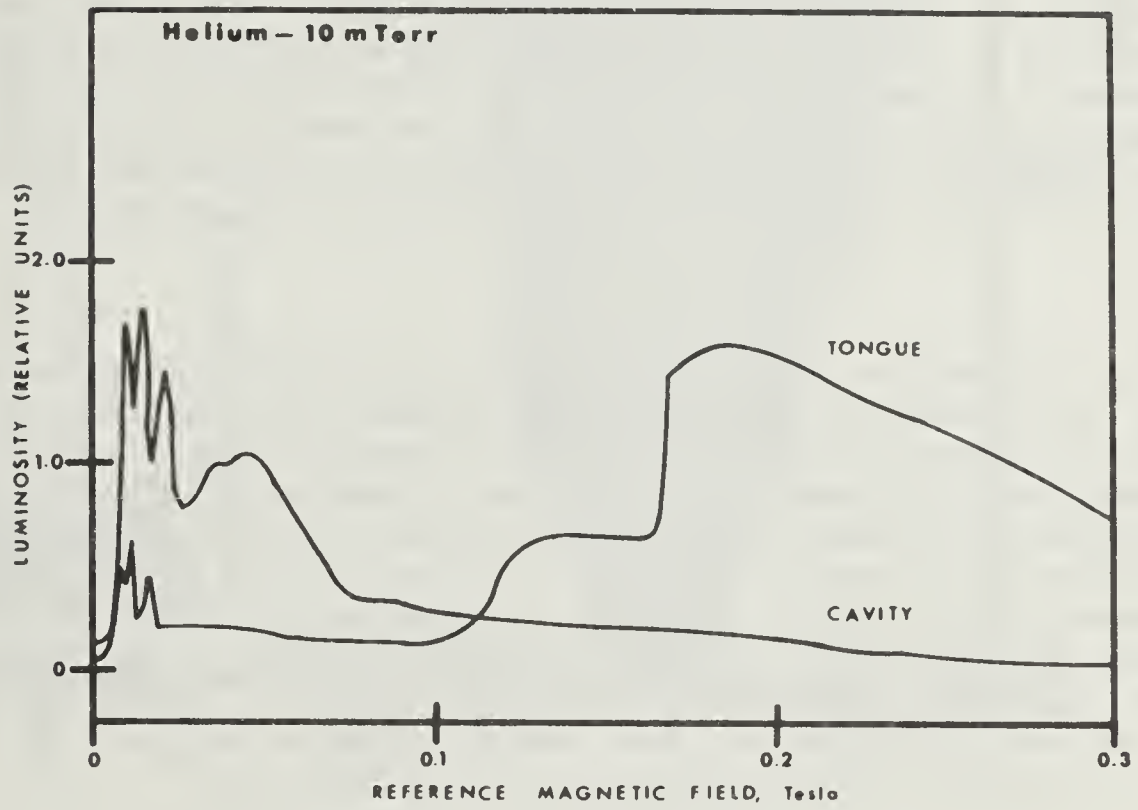

Figure 4. The intense luminosity of the ejected plasma tongue for fields greater than the cyclotron resonant field defines the jet condition. The tongue photometer sensitivity is x10 that of the cavity.

THE SUSTAINED PLASMA

Luminosity traces exhibiting neither the bounded plasma characteristics nor the jet characteristic define the "sustained plasma" operating mode. The mechanisms responsible for steady state plasma generation in this mode are assumed to be the conventional mechanisms of collisional phase mixing (Allis, 1956) and cyclotron(MacDonald, 1966) resonance.

III. DATA

The data were taken with a constant incident power of 100W. The perturbation resulting from the use of the large H-field probe was sufficient to lift the TE_{111} mode degeneracy producing a 130 MHz splitting between the cavity resonance described by an even function (TE_{111}^{e}) of the cylidrical coordinate θ, and that described by an odd function, (TE_{111}^{o}). The high frequency (TE_{111}^{e}) mode, typically had a Q of 970 in the absence of plasma. The effect of plasma loading was inferred by monitoring the corresponding mode in the diagnostic cavity. Typically we would observe the TE_{111} diagnostic cavity mode at 3.36 GHz and notice frequency shifts in the range of 20 to 70 MHz. The loaded Q's in the diagnostic cavity were typically in the range of 350 to 150.

Pressures were measured with Haystings VT-5 gauges and DV-5 gauge tubes calibrated for air. The pressure data is corrected for the specific gases. To obtain the p vs. B plots we made use of forty-three data points for argon, thirty-six data points for helium and thirty-one data points for nitrogen. The Bernstein wave resonances gradually wash out at high pressure. The exact pressure at which the process is complete is somewhat ill-defined. As the pressure is lowered, the range of magnetic field over which resonances are observed gradually narrows until only the single cyclotron resonance peak remains.

HELIUM

Fig. 5 shows the operating regions of the MACOB device using helium. The plasma no-plasma boundary defines the conditions at which the plasma is extinguished as one moves from the plasma region to a no-plasma region by changing the magnetic field at constant pressure. These boundaries depend slightly on the state of tune of the cavity and hence are only good to about 5%. We notice that at low pressure, the plasma exists only in a narrow region about the cyclotron field. Breakdown is easily initiated as the magnetic field is swept from high or low fields towards the cyclotron resonance. Bernstein wave peaks and a well-defined jet have been observed in helium. No indication of bounded plasma resonance has been observed.

ARGON

Fig. 6 represents the operating characteristics of argon. Argon exhibits all four of the plasma characteristics. A well-defined jet

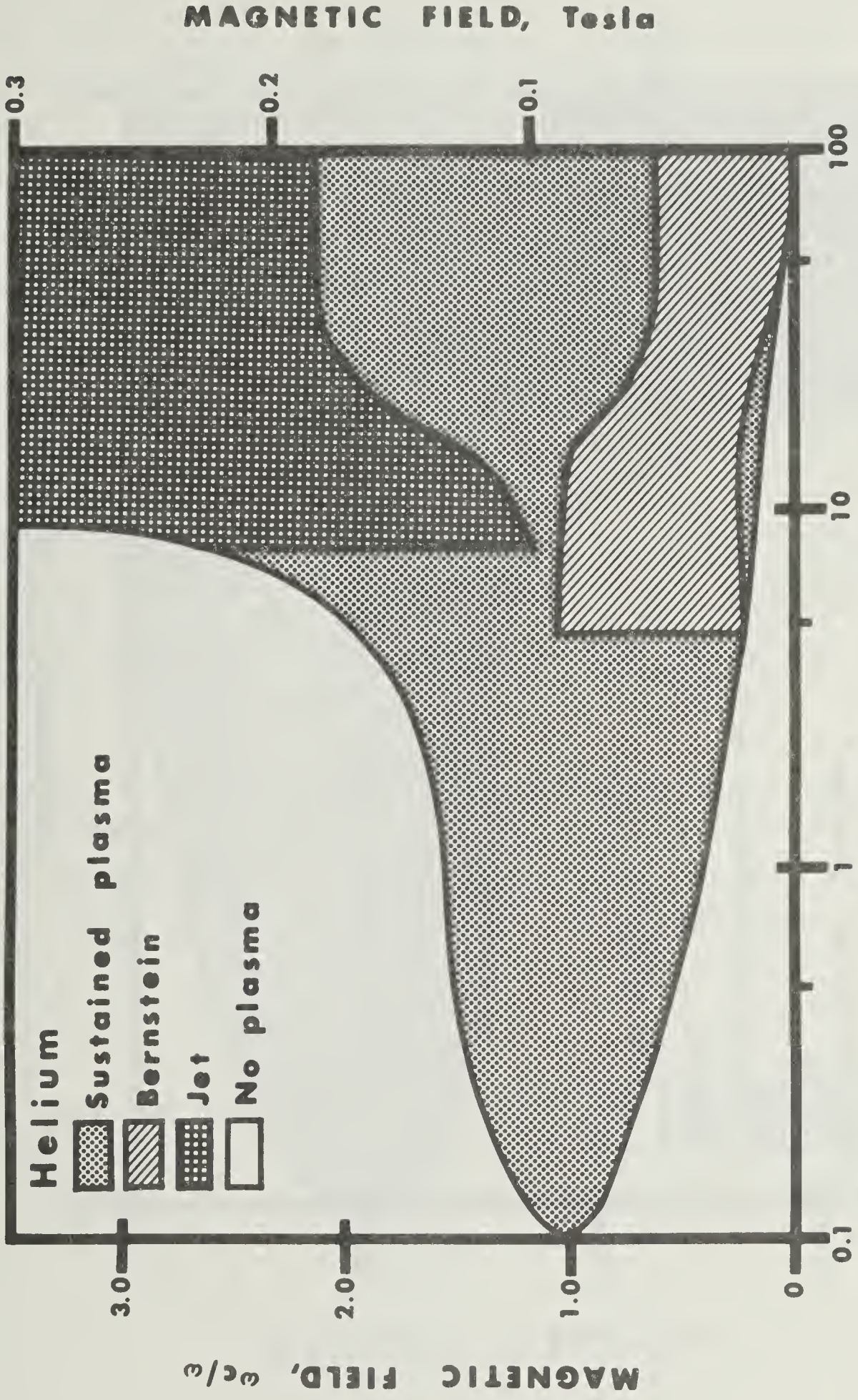

Figure 5. Helium plasma existence regions for 100W incident power and TE_{111} mode excitation.

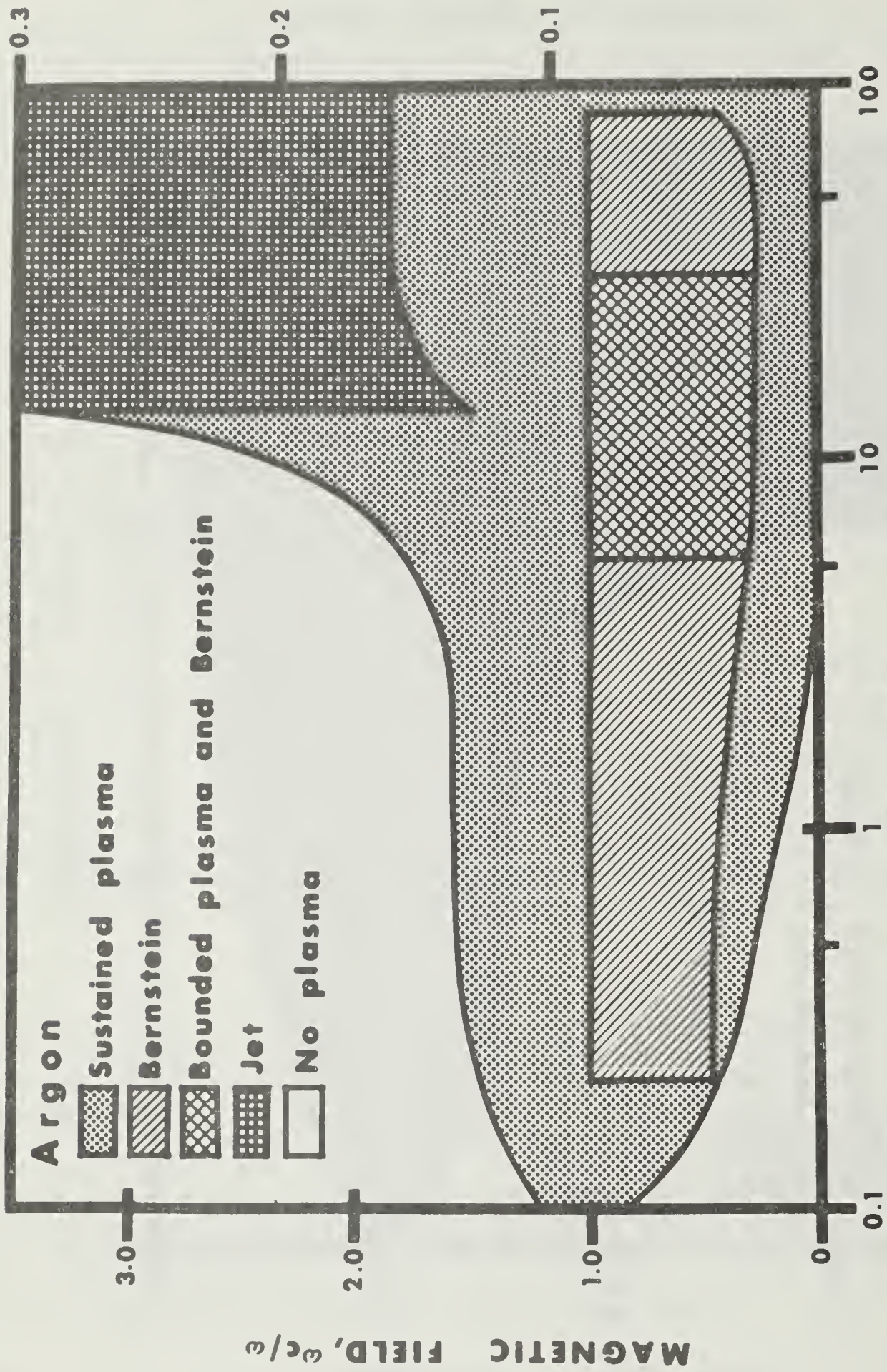

Figure 6. Argon plasma existence regions for 100W incident power and TE_{111} mode excitation.

has been observed and plasma production can take place at low pressure near cyclotron resonance. Only argon exhibits the bounded plasma behavior. There exists a range of pressures for which the bounded plasma and jet characteristics occur simultaneously.

NITROGEN

Well-defined Bernstein resonances have been observed for nitrogen and are indicated in Fig. 7. No bounded plasma behavior can be identified. A short jet was observed, but only at very high pressure. Under these conditions the high base pressure in the main chamber tends to limit the length of the jet.

IV. DISCUSSION

Consideration of the B-p diagrams for the three gases used in this study suggests that bounded plasma resonances do not play a very important role in the generation of plasma in this type of source. This conclusion has been supported by a series of measurements of plasma density using microwave cavity frequency shifts to determine the density of the plasma as it passes through the diagnostic cavity into the main chamber. The density in the driven cavity is then inferred by comparing the luminosity in the driver cavity with that in the diagnostic cavity. It is assumed (Leprince, 1968) that for constant operating pressure, plasma density is proportional to luminosity.

TABLE 1

The Bounded Plasma Resonances of the MACOB Plasma Source, $\omega_p^2 = Ne^2/m\varepsilon_0$

Cylindrical Multipole Order (m)	$\frac{\text{Plasma Density}}{\text{Cutoff Density}} = \frac{\omega_p^2}{\omega^2}$	Plasma Density N (cm^{-3})
Dipole (1)	2.28	1.70×10^{11}
Quadrupole (2)	2.82	2.10×10^{11}
Hexapole (3)	3.48	2.59×10^{11}

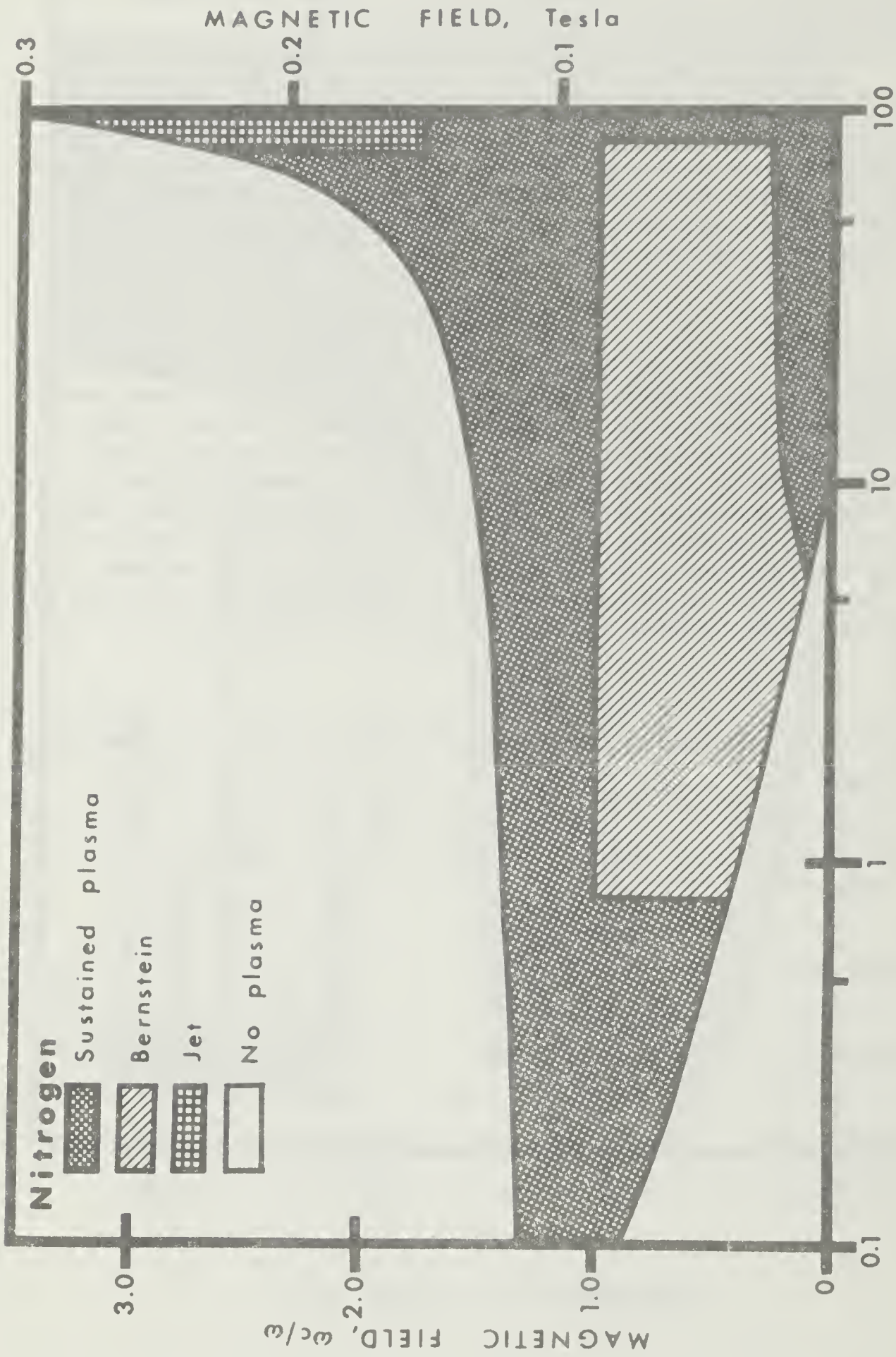

Figure 7. Nitrogen plasma existence regions for 100W incident power and TE_{111} mode excitation.

Table I indicates the densities calculated from Eq. 3 for the three lowest bounded plasma resonances which can occur in our device. The measured zero field densities are typically $1.7 \times 10^{12} cm^{-3}$. This density is more than an order of magnitude greater than that which would result if the plasma adjusted its density to maintain the dipole resonance condition. To check the possibility that we were operating in a higher order mode we systematically lowered the power to the plasma hoping to observe mode transitions. No discrete low density states were observed. Rather, the density and luminosity could be reduced continuously until it extinguished. It should be noted that discontinuous changes in luminosity could be observed for non-zero values of the magnetic field. However, the zero field density appeared to be independent of which high field mode the plasma assumed prior to reducing the field to zero.

Because of the presence of a field gradient in the plasma generation region, it is not unexpected that well-defined bounded plasma resonances are not observed. However, it is somewhat surprising that the densities are greater than that which would be achieved through the plasma resonance phenomena and that well-defined Bernstein wave resonances are observed. Consideration of Fig. 5, 6, and 7 suggest that in the pressure range of 1 to 100 mTorr, Bernstein wave generation is very prominent and might be an important energy transfer mechanism for a source like this. These results are especially surprising in the light of the work of Crawford, (Crawford, Harp, and Mantei, 1967) who found it difficult to excite Bernstein waves in a field gradient.

In Table II we present the results of a simple calculation of power absorbed by electrons in a magnetic field in the presence of electron-neutral collisions. We have also estimated the energy loss rate for plasma diffusing out of the driver cavity. The expressions used to make these estimates are given in the Appendix. We have assumed a plasma density of $5 \times 10^{11} cm^{-3}$ at a base pressure of 10 mTorr corresponding to a 2% ionization. The maximum electric field within the cavity was estimated to be 4.8×10^3 V/m using (Ingraham and Brown, 1967):

$$E_{max} = (P_{net}\, Q_\ell / \omega \eta)^{\frac{1}{2}} \qquad 5.)$$

with P_{net} = 5W and Q_ℓ = 150. η is the form factor appropriate to the cavity mode excited by the particular choice of coupling probes. The plasma volume within the cavity is $16 cm^3$. $\langle P_{lost} \rangle_{B=\infty}$ is calculated using $\Lambda = \pi/L$ for the characteristic diffusion length, an assumption which implies the lack of diffusion of particles across the magnetic field.

Table II suggests that the ordering of the gases according to the ease of plasma formation at 10 mTorr is given by Ar, N, H and He. There should be no plasma production for B = 0, but as we move toward cyclotron resonance, energy transfer to the electrons becomes very efficient. At $\omega_b = \omega[1 \pm \frac{1}{2}]$ the energy transfer to the electrons is 2.2 times the energy transfer at zero field.

TABLE II

Energy Balance Parameters for a 10 mTorr Operating Pressure.

	Argon	Nitrogen	Hydrogen	Helium
Electron-Neutral Collision Frequency, ν (sec^{-1})	(5×10^7)[a]	(4.3×10^7)[b]	(6.7×10^7)[c]	(2.6×10^7)[d]
Ionization Potential V_i (Volts)	15.76	14.54	13.60	24.58
Effective Field (B = 0) E_{eff} (Volts/meter)	7.4	6.5	10.	3.8
Power Loss (B = 0) $\langle P\rangle_{loss}$ (W)	1.6	4.7	35.	72.
Absorbed Power (B = 0) $\langle P\rangle_{abs}$ (mW)	240.	220.	330.	120.
Power Loss (B = ∞) $\langle P\rangle_{loss}$ (mW)	28.	80.	644.	1200.
Absorbed Power ($\omega_c = \omega$) $\langle P\rangle_{abs}$ (kW)	1.58	1.84	1.18	3.05

a. A. D. MacDonald, Microwave Breakdown in Gases, (John Wiley & Sons, Inc., New York, 1966), page 20.
b. Ibid. p. 161.
c. Ibid. p. 19.
d. Ibid. p. 19.

Comparison of $\langle P_{lost} \rangle_{B=\infty}$ and $\langle P_{abs} \rangle_{B=0}$ indicates that the collision frequency in argon and nitrogen is sufficient at 10 mTorr to provide the requisite energy transfer from the r.f. field to the electrons, provided we have a magnetic field strong enough to eliminate the transverse diffusion of the plasma. Enhanced energy transfer due to cyclotron resonances is not required for the maintenance of the plasma. To generate a hydrogen plasma a magnetic field equal to half the cyclotron field will provide sufficient resonant energy transfer to sustain the plasma. A helium plasma is very much dependent upon cyclotron resonance for its maintenance.

V. CONCLUSIONS

We described the MACOB plasma source and we reported the range of pressure and magnetic field for which we can generate argon, helium and nitrogen plasma. We have observed a plasma effect which we call the jet, and we have seen resonances in the plasma luminosity vs. magnetic field data which appear to be related to the presence of standing Bernstein waves. We have not been able to observe conditions in which the plasma assumes a density corresponding to a bounded plasma resonance.

We have made estimates of the rate of energy transfer from the r.f. field to the plasma. We find that for a typical plasma at a pressure of 10 mTorr that the collisional phase mixing resulting from electron-neutral collisions in argon or nitrogen is sufficient to sustain the plasma against diffusion losses in a weak magnetic field.

Estimates of the energy transfer from the r.f. field to the electrons for typical plasmas formed at a neutral gas pressure of 10 mTorr suggest that collisional phase mixing resulting from electron-neutral collisions and/or cyclotron resonant energy transfer is sufficient to account for the presence of plasma in the MACOB driver cavity. The role of standing Bernstein waves in this device is an interesting one but perhaps not a fundamental one.

ACKNOWLEDGEMENTS

We wish to express our appreciation to Mr. Robert Perry who assisted in many of the measurements and who diligently kept the MACOB source operating during the course of this work. This research was supported by the Office of Research and Projects of the Southern Illinois University at Edwardsville.

APPENDIX

Absorbed Power Density

The average absorbed power density for plasma described by a complex conductivity, $\sigma = \sigma' + j\sigma''$ is given by:

$$\langle p \rangle' = \tfrac{1}{2}(\vec{J} \cdot \vec{E}^*) = \tfrac{1}{2}\sigma' E_0^2 \qquad 6.)$$

where $\vec{E} = \vec{E}_0 \, e^{-j\omega t}$ and $\vec{J} = \sigma \vec{E}$.

Assuming $\sigma' = \frac{\omega_p^2 \varepsilon_0 \nu}{\omega^2+\nu^2}$, (Brown, 1966), we have

$$\langle p \rangle'_{abs} = \frac{Ne}{m\nu} \left(\frac{\nu^2}{\omega^2+\nu^2}\right)\left(\frac{E_0}{\sqrt{2}}\right) = \frac{Ne^2}{m\nu} E_{eff}^2 \qquad 7.)$$

where E_{eff} is the field strength of the d.c. electric field which would produce the same absorbed power density.

In the presence of a magnetic field (Brown, 1966)

$$\sigma' = \frac{\omega_p^2 \varepsilon_0 \nu}{2} \left[\frac{1}{\nu^2+(\omega-\omega_c)^2} + \frac{1}{\nu^2+(\omega+\omega_c)^2}\right] \qquad 8.)$$

and $$\langle p \rangle'_{abs} = \frac{Ne^2}{m\nu} (E_{eff})^2 \qquad 9.)$$

with $$E_{eff}^2 = \frac{\nu^2}{4} \left[\frac{1}{\nu^2+(\omega-\omega_c)^2} + \frac{1}{\nu^2+(\omega+\omega_c)^2}\right] E_0^2 \qquad 10.)$$

In our calculations we assume that the spatial variation of the TE_{111}-mode electric field over the plasma volume is adequately taken into account by replacing the $E_0 \sin kz$ dependence by the average $E_0/\sqrt{2}$. If the plasma column is taken to be uniform, the average absorbed power is given by:

$$\langle P \rangle_{abs} = \langle P \rangle'_{abs} V$$

where V is the plasma volume.

Power Lost

We assume that the rate at which plasma energy is lost to the walls of the confinement vessel is given by:

$$\langle P \rangle_{lost} = \frac{NV}{\tau} \left[E_{Ti} + E_{Te} + 3E_i\right] \qquad 11.)$$

where
- τ is the energy confinement time
- E_i is the ionization energy
- E_{Te} is the electron thermal energy $\approx E_i/3$
- E_{Ti} is the ion thermal energy ≈ 0
- V is the plasma volume = 16 cm^3

We estimate τ from the relation: $\tau = \Lambda^2/D$ 12.)
where Λ is the diffusion length given by (Brown, 1966):

$$\frac{1}{\Lambda^2} = \frac{\nu^2}{\nu^2+\omega_c^2} \left[\frac{2{\cdot}4}{r}\right]^2 + \left[\frac{\pi}{\ell}\right]^2 \qquad 13.)$$

and D is the diffusion coefficient. We use the kinetic theory

expression

$$D = \frac{v^2}{3\nu} \qquad 14.)$$

We assume that the ion sound speed is the appropriate speed to use in Eq. 14 in which case:

$$v^2 = \frac{3kT_e}{M_i} \qquad 15.)$$

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SOME CHANGES THAT HAVE OCCURRED IN THE INDIGENOUS FLORA OF TWO ADJOINING WEST-CENTRAL ILLINOIS COUNTIES (HANCOCK AND MCDONOUGH) DURING THE LAST 140 YEARS

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ABSTRACT - Changes in the indigenous flora of a Study Area consisting of two adjoining west-central Illinois counties (Hancock and McDonough) during the last 140 years are reported. Sixteen percent or 130 of the 820 native species are now considered extinct or nearly extinct, and another 68 species, rare or endangered. This reduction in the number of native species is attributed to disturbances caused by man, primarily affecting plants on the edge of their Illinois distribution and those found in wetland or aquatic habitats.

Increasing concern about the effects of man-made disturbances on our native flora and fauna has resulted in the compilation of lists of extinct and endangered species, mostly animals. It has also stimulated efforts to preserve the endangered species. The Illinois Nature Preserves Commission is compiling a list of rare and endangered Illinois plant species and this report is intended to be a contribution to this effort.

THE STUDY AREA

The Study Area which consists of two adjoining west-central Illinois counties (Hancock and McDonough), borders on the Mississippi River. It has an area of 357,260 hectares (882,432 acres) or 3626 km^2 (1,378 mi^2) which is 2.44 percent of the Illinois land area. At the time of settlement about 42 percent was forested (Telford, 1926; Myers and Wright, 1948; and Kibbe, 1952), with the remainder largely tall grass prairie. The habitats for most of the two counties are similar except for bluff, wet lands and sand areas along the Mississippi River not found in adjoining McDonough County.

The Study Area is probably unique for Illinois as extensive plant collections started in 1833, or shortly after settlement began, and have continued to the present time. These provide a base-line for some of the floristic changes that have occurred during the last 140 years including taxa that have become extinct, nearly extinct, rare and presumably endangered. In addition, data are available concerning the establishment of species from outside the Study Area that are native in Illinois, and species not native in Illinois.

Today over 91 percent of the Study Area is in farms with most of the remainder used for highways, railroads, housing and other man-related activities. The prairies have disappeared and the forested areas have been reduced from 45 percent to about 8 percent. Over 72 percent is used for crops, mostly corn and soybeans, 11 percent for pastures, and about 18 percent is artificially drained (U.S. Bureau of the Census, 1972). This has destroyed or considerably reduced the area and number of wet habitats required for a number of species. In addition to disturbances related to crop production, the environment of the remaining land area is also extensively disturbed. This includes logging and grazing of timbered areas; the use of herbicides along highways, railroads and in other places, mowing, grazing and trampling; stream and pond pollution caused by fertilizers, herbicides and other agricultural chemicals leached from crop lands, and industrial chemicals; and other man-related activities. These disturbances have eliminated or reduced the number of many native species and as a result the present vegetational cover not consisting of cultivated crops, contains many alien and native species that can tolerate these disturbances.

REVIEW OF THE LITERATURE

The report by Kibbe (1952) provides most of the data used to evaluate the floristic composition of Hancock County, and presumably also McDonough County, between 1833 and 1952. She summarized and evaluated the voucher specimens for species collected during this period by herself between 1921 and 1952, and seven earlier collectors. She made an extensive survey of the flora between 1951 and 1952 and prepared an annotated catalog for the flora of Hancock County (Kibbe, 1952). In this catalog she noted that "species not recorded since 1915 are not numbered in the present flora, but those collected since that date are numbered as they are assumed to be still represented in the flora of the county . . . " Nearly all of the species "not numbered" she annotated as "not recently found."

The extensive collections made by Henry in Hancock County since 1964 and by Myers (Myers and Wright, 1948; Myers, 1972 and 1975) since 1944 in McDonough County provide data for the present floristic composition of the Study Area. Voucher specimens for Hancock County are deposited in the Alice L. Kibbe Herbarium (WARK), Warsaw, Illinois; and those for McDonough County are in the Western Illinois University Herbarium (MWI), Macomb. Collection records and evaluation of voucher specimens for the two counties in the Study Area have also been obtained from Jones and Fuller (1955), Winterringer and Evers (1960), and for the Orchidaceae, from Sheviak (1974).

TAXA LISTED BY KIBBE (1952) NOW CONSIDERED EXTINCT, NEARLY EXTINCT

RARE OR ENDANGERED IN THE STUDY AREA

The native plants listed below were derived from the report by Kibbe (1952) on the flora of Hancock County on the basis of her annotations concerning their occurrence from 1833 to 1952. Not included are taxa not supported by voucher specimens and species misidentified according to Jones and Fuller (1955), and Sheviak (1974). Species that Kibbe (1952) indicated had not been collected between 1915 and 1952 are annotated with an asterisk and those not collected since 1964 in Hancock County, or since 1945 in McDonough County, are annotated with an X. The data concerning habitats, local distribution, and nomenclature are from Jones (1963) and that for taxa on the edge of their Illinois distribution or disjunct in the Study Area is derived from Winterringer and Evers (1960), and Sheviak (1974).

POLYPODIACEAE

* *Athyrium angustum* (Willd.) Presl Collected in Hancock County, and reported for McDonough County in 1971. Local distribution.

* *Dryopteris marginalis* (L.) Gray McDonough County collection in 1948.

X *Matteuccia struthiopteris* (L.) Todaro "Nearly exterminated" (Kibbe, 1952). On S edge of Illinois distribution. Wet habitats may be destroyed. Local distribution.

* *Pteridium latiusculum* (Desv.) Hieron. McDonough County collection in 1950.

ACANTHACEAE

Dianthera americana L. "A rare plant at present" (Kibbe, 1952). Collected in Hancock County. Its wet habitats may be disappearing.

APOCYNACEAE

X *Amsonia tabernaemontana* Walt. Considered "very rare" by Kibbe (1952). Near NW edge of Illinois distribution. Local distribution. Wet habitats may be destroyed.

AQUIFOLIACEAE

X* *Ilex decidua* Walt. "Rare having been found at only one station during present survey" (Kibbe, 1952). On N edge of Illinois distribution. Wet habitats may be destroyed.

ARALIACEAE

X* *Aralia nudicaulis* L. Local distribution. Moist habitats may be destroyed.

ASCLEPIADACEAE

X *Asclepias amplexicaulis* Sm. Considered "very rare" by Kibbe (1952).

X* *A. meadii* Torr.

X* *A. viridiflora* Raf. Local distribution.

BORAGINACEAE

X *Onosmodium hispidissimum* Mack. "Occasional" (Kibbe, 1952). Local distribution.

CALLITRICHACEAE

* *Callitriche heterophylla* Pursh McDonough County collection in 1969. Its aquatic habitats may be disappearing. Local distribution.

CAMPANULACEAE

X* *Campanula aparinoides* Pursh Near S edge of Illinois distribution. Its wet habitats may be destroyed. Local distribution.

CARYOPHYLLACEAE

* *Silene nivea* (Nutt.) Otth. McDonough County collection in 1968. Local distribution.

* *Stellaria longifolia* Muhl. McDonough County collection in 1968. Its moist habitats may be disappearing.

CERATOPHYLLACEAE

X* *Ceratophyllum echinatum* Gray An aquatic whose habitats may be destroyed. Reported for only three other counties (Henderson, Ogle and Kankakee). Local distribution.

COMPOSITAE

X* *Agoseris cuspidata* (Pursh) D. Dietr. On S edge of distribution.

X *Ambrosia coronopifolia* T. & G. "Only one specimen found during present survey (Kibbe, 1952). A weedy species near S edge of Illinois distribution.

Aster anomalus Engelm. "Rare" and "only one station" (Kibbe, 1952). McDonough County collection in 1948. Near N edge of Illinois distribution.

X* *A. furcatus* Burgess Near S edge of Illinois distribution and local.

X* *A. linariifolius* L.

A. oblongifolius Nutt. "A rather rare plant" (Kibbe, 1952). Collected in Hancock County. Local distribution.

X* A. sericeus Went. Local distribution.

X Cacalia muhlenbergii (Sch.-Bip.) Fern. Considered "very rare" by Kibbe (1952). Moist habitats may be destroyed.

X* C. suaveolens L. Local distribution.

Cirsium hillii (Canby) Fern. "Rather rare" (Kibbe, 1952). McDonough County collection in 1946.

X C. muticum Michx. Near S edge of Illinois distribution. Wet habitats may be destroyed.

X Dyssodia papposa (Vent.) Hitchc. "Abundant at several stations" (Kibbe, 1952). Local distribution.

* Helenium nudiflorum Nutt. Collected in McDonough County. Near N edge of Illinois distribution.

X Helianthus occidentalis Riddell "Occasionally, . . . nowhere abundant" (Kibbe, 1952).

X* Lactuca ludoviciana (Nutt.) Riddell

X Prenanthes crepidinea Michx. Considered "rare" by Kibbe (1952). Local distribution.

X* P. racemosa Michx. Moist habitats may be destroyed.

X Solidago rugosa Mill. "Fairly abundant at two or three stations" (Kibbe, 1952). Moist habitats may be destroyed.

X S. speciosa Nutt. "Nowhere abundant" (Kibbe, 1952).

* Verbesina helianthoides Michx. McDonough County collection in 1971. Near N edge of Illinois distribution.

CONVOLVULACEAE

* Convolvulus spithamaeus L. McDonough County collection in 1950 and collected in Hancock County. Local distribution.

X* Cuscuta coryli Engelm.

X C. glomerata Choisy "Abundant at several stations" (Kibbe, 1952).

CRUCIFERAE

X* Arabis confinis Wats. Disjunct in Study Area.

X* A. pycnocarpa Hopkins Local distribution. Wet habitats may be destroyed.

* A. virginica (L.) Poir. McDonough County collection in 1963. Near N edge of Illinois distribution.

* Iodanthus pinnatifidus (Michx.) Steud. Collected in Hancock County. Local distribution.

X Neobeckia aquatica (A. Eaton) Greene "Rare" and found "at but few stations" (Kibbe, 1952). An aquatic whose habitats may be destroyed. Local distribution.

CUCURBITACEAE

X Echinocystis lobata (Michx.) T. & G. "Occasional" (Kibbe, 1952). Local distribution.

EUPHORBIACEAE

* Acalypha gracilens Gray McDonough County collection in 1948.

X* Chamaesyce humistrata (Engelm.) Small Local distribution.

X* Croton capitatus Michx. "Never abundant" (Kibbe, 1952).

X C. monanthogynus Michx. "Not abundant" (Kibbe, 1952). Near N edge of Illinois distribution.

X* Euphorbia obtusata Pursh Local distribution. Moist habitats may be destroyed.

GENTIANACEAE

Gentiana flavida Gray "Rare" (Kibbe, 1952). McDonough County collection in 1971. Moist habitats may be disappearing.

X G. quinquefolia L. "Very rare now" (Kibbe, 1952).

HALORAGACEAE

X* Myriophyllum heterophyllum Michx. Local distribution. An aquatic whose habitats may be destroyed.

X M. pinnatum (Walt.) BSP. "No doubt will become extinct" (Kibbe, 1952). Near N edge of Illinois distribution. An aquatic whose habitats may be destroyed.

X* Proserpinaca palustris L. Local distribution and disjunct in Study Area. An aquatic whose habitats may be destroyed.

HYPERICACEAE

* Hypericum canadense L. Collected in Hancock County. Moist habitats may be disappearing. Near S edge of Illinois distribution.

X* H. gymnanthum Engelm. & Gray Local distribution. Wet habitats may be destroyed.

JUGLANDACEAE

Carya illinoensis (Wang.) K. Koch "Formerly very abundant near the river, but comparatively few trees left" (Kibbe, 1952). Collected in Hancock County.

X C. laciniosa (Michx. f.) Loud. "Not abundant" (Kibbe, 1952). Near N edge of Illinois distribution and local. Moist habitats may be destroyed.

LABIATAE

* Agastache scrophulariaefolia (Willd.) Ktze. McDonough County collection in 1946. Local distribution.

* Isanthus brachiatus (L.) BSP. Collected in Hancock County. Local distribution.

X Teucrium occidentale Gray "Rare, . . . only record" for Hancock County was in 1917 (Kibbe, 1952). Near S edge of Illinois distribution and local. Moist habitats may be destroyed.

LEGUMINOSAE

X* Desmanthus illinoensis (Michx.) MacM. On edge of Illinois distribution and local.

X Desmodium canescens (L.) DC. "Fairly abundant" (Kibbe, 1952).

X D. nuttallii (Schindl.) Schubert Considered "rare" by Kibbe (1952). Disjunct distribution in Study Area.

* D. nudiflorum (L.) DC. Collected in Hancock County.

X* Lathyrus venosus Muhl. Disjunct distribution in Study Area.

X* Lespedesa intermedia (Wats.) Britt. On N edge of Illinois distribution.

LENTIBULARIACEAE

X Utricularia vulgaris L. "Drainage has resulted in very nearly exterminating this probably once abundant species" (Kibbe, 1952). An aquatic whose habitats now have probably been destroyed.

LOBELIACEAE

Lobelia cardinalis L. Considered "rare" by Kibbe (1952). Collected in Hancock County. Wet habitats may be disappearing.

LYTHRACEAE

X* Peplis diandra Nutt. Its wet habitats may be destroyed.

X* Rotala ramosior (L.) Koehne Its wet habitats may be destroyed.

MARTYNIACEAE

X* Proboscidea louisianica (Mill.) Thell. Its distribution is local in most of Illinois, but since it has been cultivated as a vegetable, some of these records may be for escapes. Dr. S. B. Mead in 1875 considered it introduced to Hancock County and noted it as "spontaneous about cultivated places, occasionally", but A. B. Tandy collected it in 1904 "far from cultivated land" (Kibbe, 1952). In Indiana, Deam (1940) collected it three times "each . . . introduced by some means or other." Jones and Fuller (1955) considered it native in S Illinois, but probably adventive northward.

ONAGRACEAE

* Ludwigia palustris (L.) Ell. McDonough County collection in 1956. Local distribution. Its wet habitats may be disappearing.

PLANTAGINACEAE

X* Plantago purshii R. & S. On S edge of Illinois distribution.

X* P. pusilla Nutt. On N edge of Illinois distribution.

PODOPHYLLACEAE

X Caulophyllum thalictroides (L.) Michx. Considered "very rare" by Kibbe (1952).

POLEMONIACEAE

X* Phlox glaberrima L.

X* P. maculata L. On S edge of Illinois distribution. Moist habitats may be destroyed. Local distribution in N half of state.

POLYGALACEAE

X* Polygala incarnata L.

P. senega L. Considered "very rare" by Kibbe (1952). Collected in Hancock County. Local distribution.

POLYGONACEAE

X* Polygonum hydropiperoides Michx. "Not widely distributed" (Kibbe, 1952). On S edge of Illinois distribution. Its moist habitats may be destroyed.

* P. tenue Michx. McDonough County collection in 1948.

PRIMULACEAE

X* Centunculus minimus L. On N edge of Illinois distribution. Moist habitats may be destroyed.

Lysimachia quadriflora Sims "Rare at present, but apparently much more abundant in Dr. Mead's day" (Kibbe, 1952). Collected in Hancock County. Local distribution. Its moist habitats may be disappearing.

X Samolus parviflorus Raf. "Not abundant" (Kibbe, 1952). Its wet habitats may be destroyed.

RANUNCULACEAE

X Anemone cylindrica Gray "Rather rare" (Kibbe, 1952).

X Hydrastis canadensis L. Considered "rare" by Kibbe (1952). Local distribution.

Ranunculus fascicularis Muhl. "Very rare now" and found at "only one station" (Kibbe, 1952). McDonough County collection in 1968.

X* R. laxicaulis (T. & G.) Darby On N edge of Illinois distribution. Wet habitats may be destroyed.

X R. trichophyllus Chaix Collected in 1926 in Hancock County and reported in 1876 to be "frequent in Mississippi bottoms" (Kibbe, 1952). On S edge of its major Illinois distribution. An aquatic whose habitats may be destroyed.

ROSACEAE

* Agrimonia rostellata Wallr. Collected in McDonough County. Near N edge of Illinois distribution.

Crataegus calpodendron (Ehrh.) Medic. "Rare" and found at "few stations" (Kibbe, 1952). McDonough County collection in 1968.

X C. punctata Jacq. "Nowhere abundant" (Kibbe, 1952).

X C. viridis L. "A rare species here" (Kibbe, 1952). On N edge of Illinois distribution.

* Gillenia stipulata (Muhl.) Trel. Collected in McDonough County. Near N edge of Illinois distribution.

X* Physocarpus opulifolius (L.) Maxim. "At present little trace of it" (Kibbe, 1952). Local distribution.

X Prunus nigra Ait. "Moderately abundant" (Kibbe, 1952).

X Rosa suffulta Greene "Abundant on open hillside and in sparsely wooded ravines" Kibbe (1952).

RUBIACEAE

X Galium asprellum Michx. Disjunct distribution in the Study Area. Wet habitats may be destroyed.

SALICACEAE

X Salix rigida Muhl. Wet habitats may be destroyed.

SAURURACEAE

X* Saururus cernuus L. Local distribution. Wet habitats may be destroyed.

SCROPHULARIACEAE

* Aureolaria pedicularia (L.) Raf. Collected in McDonough County. Disjunct distribution in Study Area.

* Chelone glabra L. McDonough County collection in 1970. Local distribution. Its wet habitats may be disappearing.

X C. obliqua L. "Only one station noted" (Kibbe, 1952).

Collinsia verna Nutt. Considered "rare" by Kibbe (1952). Collected in Hancock County. Its moist habitats may be disappearing. Local distribution.

* Gerardia auriculata Michx. "A rare plant" and collected at "only one station during present survey" (Kibbe, 1952). Collected in Hancock County.

* G. purpurea L. The Hancock County record is from 1852 but collected in McDonough County in 1950. Moist habitats may be destroyed.

* Gratiola neglecta Torr. Collected in Hancock County, and in McDonough County in 1974. Its wet habitats may be disappearing.

X* G. virginiana L. Its wet habitats may be destroyed.

* Pedicularis lanceolata Michx. McDonough County collection in 1971. Its wet habitats may be disappearing.

SOLANACEAE

* Physalis pubescens L. Collected in Hancock County. Local distribution.

UMBELLIFERAE

X* Erigenia bulbosa (Michx.) Nutt. Hancock County records are for 1843 and 1862. On W edge of Illinois distribution. Local distribution.

VERBENACEAE

X* Verbena canadensis (L.) Britt. "A rare plant located at only one station" (Kibbe, 1952). Local distribution.

X* V. simplex Lehm.

VIOLACEAE

X* Viola cucullata Ait. Local distribution. Wet habitats may be destroyed.

VITACEAE

X Vitis aestivalis Michx. "Not abundant" (Kibbe, 1952).

ALISMACEAE

* Sagittaria rigida Pursh Collected in Hancock County. Its wet habitats may be disappearing.

COMMELINACEAE

X* Tradescantia subaspera Ker On N edge of major Illinois distribution.

T. virginica L. Considered "very rare" by Kibbe (1952). McDonough County collection in 1968. On N edge of Illinois distribution.

CYPERACEAE

X* Carex albolutescens Schw. Local distribution.

* C. artitecta Mack. McDonough County collection in 1969. Local distribution.

X* C. atherodes Spreng. Disjunct distribution in the Study Area as there is only one other collection reported: in N Illinois (Winnebago County). Its wet habitats may be destroyed.

X* C. buxbaumii Wahl. At S and W edge of Illinois distribution. Its bog and marsh habitats probably destroyed.

X* C. conoidea Schk. On S edge of Illinois distribution and its wet habitats probably destroyed. Local distribution.

* C. crinita Lam. Recorded for McDonough County in 1971. Marsh habitats being destroyed.

X C. cruscorvi Shuttlew. "Once abundant, but rapidly diminishing, as swamp lands are drained" (Kibbe, 1952). Its swampy habitats are probably destroyed.

* C. granularis Muhl. Collected in Hancock County, and reported for McDonough County in 1968.

* C. grayii Carey Collected in Hancock County.

* C. hirtifolia Mack. McDonough County collection in 1968.

X* C. intumescens Rudge On SW edge of Illinois distribution. Swampy habitats may be destroyed.

* C. jamesii Schw. McDonough County collection in 1968.

* C. lacustris Willd. McDonough County collection in 1964. Local distribution. Wet habitats may be disappearing.

X* C. muskingumensis Schw. "Not abundant" (Kibbe, 1952). Wet habitats may be destroyed. Local distribution.

* C. oligocarpa Schk. McDonough County collection in 1967.

X C. richardsonii R. Br. On S edge of Illinois distribution.

X* C. rostrata Stokes On S edge of Illinois distribution. Wet habitats may be destroyed. Local distribution.

* C. scoparis Schk. Collected in McDonough County. Wet habitats may be disappearing.

X* C. sprengelii Dewey At S edge of Illinois distribution.

X* C. suberecta (Olney) Britt. At S and W edge of Illinois distribution. Wet habitats may be destroyed.

* C. trichocarpa Muhl. At S edge of Illinois distribution. Wet habitats may be disappearing. McDonough County collection in 1951.

X* C. tuckermani Dewey Disjunct in Study Area as considerably S of its Illinois distribution. Wet habitats may be destroyed.

* C.vesicaris L. McDonough County collection in 1950. Local distribution. Wet habitats may be disappearing.

* Cyperus rivularis Kunth McDonough County collection in 1974. On S edge of Illinois distribution. Wet habitats may be disappearing.

* Eleocharis compressa Sulliv. Collected in McDonough County. Wet habitats may be disappearing.

X Hemicarpa micrantha (Vahl) Pax Considered "almost extinct" by Kibbe (1952). Local distribution. Wet habitats may be destroyed.

X Scirpus polyphyllus Vahl "Common in swamps . . . throughout" (Kibbe, 1952). Near N edge of Illinois distribution. Wet habitats may be destroyed.

X* S. purshianus Fern. Collected in only two other counties. Wet habitats may be destroyed.

X* Scleria triglomerata Michx. At S edge of Illinois distribution. Moist habitats may be destroyed.

GRAMINEAE

* Agrostis perennans (Walt.) Tuckerm. McDonough County collection in 1968. Local distribution.

X Alopecurus aequalis Sobol. "Abundant at numerous stations along streams" (Kibbe, 1952). Wet habitats may be destroyed.

X* Aristida dichotoma Michx. On N edge of Illinois distribution.

* Brachyelytrum erectum (Schreb.) Beauv. Considered "rare" by Kibbe (1952). Collected in Hancock County. Local distribution.

* Diarrhena americana Beauv. McDonough County collection in 1974. Local distribution.

X Koeleria cristata (L.) Pers. "Rather widespread, but it is nowhere abundant" (Kibbe, 1952). Local distribution.

* Leersia lenticularis Michx. Collected in Hancock County. Local distribution except for the N counties. Wet habitats may be disappearing.

X Melica mutica Walt. Local distribution.

M. nitens (Scribn.) Nutt. Kibbe (1952) considered it "rare." Collected in Hancock County.

* Muhlenbergia racemosa (Michx.) BSP. Collected in McDonough County. Wet habitats may be disappearing.

X *M. sylvatica* Torr. Kibbe (1952) considered it "fairly abundant." At S edge of Illinois distribution.

X* *M. tenuiflora* (Willd.) BSP.

X* *Panicum agrostoides* Spreng. Near N edge of Illinois distribution. Local distribution except for N counties. Moist habitats may be destroyed.

X* *P. leibergii* (Vasey) Scribn. Near S edge of Illinois distribution. Local distribution.

X *P. lindheimeri* Nash Kibbe (1952): "Grows abundantly on prairies and in open grounds."

X *P. praecocius* Hitchc. & Chase Kibbe (1952): "Fairly abundant in dry woods and on sandy soils." Near S edge of major Illinois distribution.

X *Paspalum ciliatifolium* Michx. Kibbe (1952): "rare."

Phragmites communis Trin. Considered "rare" by Kibbe (1952). Collected in Hancock County. Near S edge of Illinois distribution and local in N and central counties. Wet habitats being destroyed.

* *Poa palustris* L. McDonough County collection in 1951. On SW edge of Illinois distribution. Wet habitats may be disappearing. Local distribution in N half of state.

X *Sporobolus vaginflorus* (Torr.) Wood "Abundant at a few stations" (Kibbe, 1952).

X *Stipa spartea* Trin. Kibbe (1952): "Abundant on plains and prairies." Local distribution in N half of state.

* *Tripsacum dactyloides* L. McDonough County collection in 1946. On N edge of Illinois distribution. Wet habitats may be destroyed. Local distribution in S half of state.

JUNCACEAE

* *Juncus acuminatus* Michx. "It seems strange that a plant so abundant as this species must have been in Dr. Mead's day, should not have been collected during the present survey" (Kibbe, 1952). Collected in McDonough County. Wet habitats may be disappearing.

X* *J. nodatus* Coville Disjunct distribution in the Study Area. Swampy habitats may be destroyed. Local distribution.

LILIACEAE

X Allium mutabile Michx. Considered rare by Kibbe (1952). At W edge of Illinois distribution and reported for only two northeastern and one southern county. Local distribution.

X* A. tricoccum Ait. Near S edge of Illinois distribution.

X* Medeola virginiana L. Disjunct in Study Area and considerably SW of its Illinois distribution.

X Smilax glauca Walt. Considered "rare" by Kibbe (1952). Disjunct in Study Area as N of its Illinois distribution.

X* Trillium gleasoni Fern. Local distribution.

X* T. sessile L. Disjunct in Study Area and W of its Illinois range.

X* Veratrum woodii Robbins. At S edge of Illinois distribution.

ORCHIDACEAE

X* Aplectrum hyemale (Muhl.) Torr.

X* Calopogon pulchellus (Salisb.) R. Br.

X* Corallorhiza trifida Chat. Disjunct in Study Area as Mohlenbrock (1970) lists it only for St. Clair County. But Sheviak (1974) provisionally accepts Mead's record for Hancock County.

X* Cypipedium candidum Muhl. At S edge of major Illinois distribution. Its wet prairie habitats probably destroyed.

X C. parviflorum Salisb. Kibbe (1952): "practically extinct." Its moist or wet habitats probably destroyed.

X* C. reginae Walt. At S edge of Illinois distribution. Its wet habitats probably destroyed.

X* Habenaria hookeri Torr. ex Gray Disjunct in Study Area as considerably S of its Illinois distribution (Lake and Cook counties).

X H. lacera (Michx.) Lodd. Considered "very rare" by Kibbe (1952). Its wet habitats probably destroyed.

* H. leucophaea (Nutt.) Gray Considered "rare" by Kibbe (1952). McDonough County collection in 1950. Its wet habitats probably destroyed.

X* Malaxis unifolia Michx. Reported for only two other counties (Henderson and Menard).

* Spiranthes cernua (L.) Rich. (S. magnicamporum Sheviak) McDonough County collection in 1946. Wet habitats being destroyed. Local distribution.

S. gracilis (Bigel.) Beck Considered "rare" by Kibbe (1952). Collected at several stations in McDonough County in 1974 where numerous plants were noted. Local distribution.

X* S. lucida (H.H. Eaton) Ames Disjunct in Study Area as SW of its Illinois distribution (Will and Woodford counties). Its wet habitats probably destroyed.

POTAMOGETONACEAE

* Potamogeton diversifolius Raf. McDonough County collection in 1951. Aquatic habitats may be disappearing.

X* P. epihydrus Raf. At S edge of Illinois distribution and collected in only two other counties (Fulton and Lake). Aquatic habitats may be altered or destroyed.

X* P. friesii Rupr. Disjunct in Study Area as considerably SW of its Illinois distribution (Lake and Cook counties). Aquatic habitats may be altered or destroyed.

SPARGANIACEAE

X* Sparganium androcladum (Engelm.) Morong At W edge of Illinois distribution. Wet habitats may be altered or destroyed.

DISCUSSION

This report, using data derived from published records and collections made largely by the authors, documents changes that have occurred in the indigenous flora of two adjoining west-central Illinois counties during the last 140 years. The data for the species listed above which are summarized in Table 1 indicate that 130 of the 820 native species reported by Kibbe (1952) are extinct or nearly extinct, and that:

1. These are almost 16 percent of the native species reported by Kibbe (1952) and include 6.5 percent of the plants she did not consider extinct in 1952.

2. About 40 percent are aquatics or have moist or wet habitats.

3. Half were disjunct or on the edge of their Illinois distribtion in the Study Area.

4. One-third have a local or scattered Illinois distribution.

The data also indicate that the remaining 68 of the 198 species on the list are probably rare or endangered in the Study Area. It should be emphasized, however, that further collections might change the status of some of these plants: e.g. two species were collected in 1974.

The data could also be interpreted as indicating that the extensive disturbances that have occurred in a largely agricultural area during the last 140 years have eliminated many species that were on the edge of their Illinois distribution, that had aquatic or moist habitats, or a local distribution. It also indicates that distribution maps for many less common species should be reevaluated on the basis of their collection dates because many probably have a more restricted distribution today.

TABLE 1. Status of 198 taxa considered extinct, nearly extinct, rare or endangered in the Study Area; and data on their habitats and distribution in Illinois.

Species category*	All species on the list (Total: 198)	Species not collected in Hancock County since 1964 or since 1946 in McDonough County (Total:130)
Considered extinct in Hancock County by Kibbe in 1952.	130 (65.2%)	77 (59.2%)
Not considered extinct by Kibbe in 1952.	68 (34.8%)	53 (40.8%)
Considered extinct by Kibbe in 1952 but collected in the Study Area.	52 (26.3%)	---
Aquatic, wet or moist habitats.	90 (45.4%)	57 (43.8%)
Disjunct or on edge of Illinois distribution in the Study Area	80 (40.2%)	65 (50.0%)
Local distribution in Illinois	69 (34.8%)	43 (33.1%)

* A number of species are listed in more than one category so the total exceeds 198, and 100 percent.

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ADDENDUM

Henry (1976) reported 84 new records for Hancock County for the period between 1965 and 1974. Of these, 41 (48.8 percent) are aliens and 43 (51.2 percent) are native. He notes that "this relatively high proportion of alien species probably reflects the destruction of native plant habitats by man's activities (principally associated with agricultural practices) and the replacement in the disturbed areas by alien disturbophytes." An analysis of these new records indicates that 8 (18.6 percent) of the native species and 30 (73.2 percent) of the aliens are weeds in Illinois or elsewhere.

HENRY, R. D. 1976. Additions to the vascular flora of Hancock County, Illinois. Trans. Ill. State Acad. Sci. (In press).

TRANSACTIONS, ILL. STATE ACAD. SCI.
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COMPARISONS OF MORPHOLOGY, LACTATE DEHYDROGENASE, AND DISTRIBUTION OF *RANA BLAIRI* AND *RANA UTRICULARIA* IN ILLINOIS AND MISSOURI

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ABSTRACT

R. blairi and *R. utricularia*, two species of leopard frogs, differ in morphology and breeding call characteristics. Electrophoresis shows that they also differ in lactate dehydrogenase (LDH) phenotype. The LDH pattern was used to assign species identity to egg masses and tadpoles. The two species showed wide overlap of breeding space along the Mississippi River in southern Illinois and Missouri. Partial distributional separation was indicated. Hybrids were not found in the numbers predicted by the Hardy-Weinberg Law. This suggests that the two species are reproductively isolated.

INTRODUCTION

Leopard frogs (*Rana pipiens* complex) are common in the U.S.A., including the midwestern states of Illinois and Missouri. J. A. Moore's (1944) monograph on the taxonomy of leopard frogs concluded that they were a single widely distributed species with great morphological variation. In recent years several workers have shown that the complex is composed of sibling species. Brown (1973), Mecham *et. al.* (1973) and Pace (1974) review that evidence. The most recent taxonomic revision of the complex is that of Pace (1974). She recognized three species in Illinois and Missouri on the basis of morphology and breeding call characteristics--*R. blairi*, *R. utricularia*, and *R. pipiens*. The *R. utricularia* populations were formerly called *R. p. sphenocephala* by some authors. A request has been made by Brown *et. al.* (1976) to The International Commission on Zoological Nomenclature for the suppression of the name *R. utricularia* in favor of the name *R. sphenocephala*. This paper is restricted to the two species found in the more southern parts of Illinois and Missouri. The range of *R. blairi*, the plains leopard frog, extends across the plains and prairie portions of the Texas Panhandle, Oklahoma, Kansas, Nebraska, Iowa, Missouri, and Illinois (Brown and Brown, 1972; Conant, 1975; Dunlap and Kruse, 1976; Funk, 1975; Littlejohn and Oldham, 1968; Mecham *et. al.*, 1973; Pace, 1974). *R. utricularia*, the southern leopard frog, occurs from New York south through Florida and as far west as the eastern portions of Texas, Oklahoma and Kansas. It is found in the southern halves of Illinois and

Missouri (Brown and Brown, 1972; Conant, 1975; Dunlap and Kruse, 1976; Funk, 1975; Littlejohn and Oldham, 1968; Pace, 1974). Pace stated (1974:79) that sympatry of these species might be more extensive in the Mississippi River Valley than in any other area where their ranges meet. R. blairi and R. utricularia differ in their dorsolateral folds, snout sports, vocal sacs, and in the character of their male breeding calls (Brown and Brown, 1972; Mecham et. al., 1973; Pace, 1974).

Lactate dehydrogenase (LDH) is a high molecular weight glycolytic enzyme. In most higher vertebrates five isozymes of LDH can be resolved. These are due to the aggregation into tetramers of two kinds of subunits (heart and skeletal muscle), each under separate genetic control (Kaplan, 1964; Markert, 1968). Genetic variants in the locus controlling the heart subunit in the R. pipiens complex have been found by Axtell (1974), Salthe (1969), Wright (1968), Wright and Moyer (1968), and Wright and Subtelny (1971). Those authors conducted electrophoretic studies of the results of breeding experiments. Their evidence indicates that the variant heart subunits are controlled by alleles at a single genetic locus. They consistently found a hybrid LDH pattern in embryos produced by crossing adults homozygous for different heart allotypes. Salthe (1969) found no ontogenetic changes in the electrophoretic characteristics of LDH's in the R. pipiens complex. Salthe (1969) found twelve heart (HLDH) allotypes in the R. pipiens complex. The distribution of his PIP I HLDH included the geographic ranges of R. blairi and R. pipiens. Although they presented no evidence to substantiate their claim, Mecham et. al. (1973:9) stated that R. blairi possesses Salthe's PIP I HLDH and can be distinguished from R. sphenocephala (R. utricularia) by HLDH. Salthe (1969) found that PIP III HLDH was prevalent within the geographic range of R. utricularia. He reported PIP III HLDH from northeastern Oklahoma where Littlejohn and Oldham (1968) recorded the call of R. utricularia. Wright (1968) reported PIP III HLDH from Pacific, Franklin Co., Missouri.

The object of this paper is to study the relationships between R. blairi and R. utricularia with regard to LDH phenotype, adult morphology, male breeding call, and overlap in use of breeding ponds in southwestern Illinois and eastern Missouri.

MATERIALS AND METHODS

Between June 1972 and September 1973 specimens were collected from the localities listed in Table 1 and mapped in Figure 1. Eggs were allowed to hatch before electrophoresis. Starch gel electrophoresis was performed on ground tissue (liver or kidney in adults and tadpoles; whole organism with hatchlings) using a citrate-phosphate buffer, pH 6.9 (Ruddle and Nichols, 1971:121) and followed by staining for LDH according to the procedures of Selander et. al. (1971:89). On the basis of the LDH data, gene frequency estimates (percentage of HLDH genes of R. blairi) were made for the populations. Sixty-five preserved adult and juvenile specimens were examined for both morphologic characters and LDH phenotype. The following morphologic characters were recorded: 1) dorsolateral ridges--The dorsolateral ridges may be complete posteriorly or broken by dashes or "broken anterior to the thigh, the posterior segment being deflected dorsally and continuing

TABLE 1. Collection Localities for *Rana blairi* and *Rana utricularia* (Ad. = adults; Tad. = tadpoles; Juv. = juveniles; Egg = Egg Clutch)

No.	Locality	Latitude-Longitude	R. blairi	R. utricularia	% R. blairi
1	Marshall Co., Ill.	41°05'N-89°16'W	11 juv.		100
2	Peoria Co., Ill.	40°37'N-89°43'W	27 tad. 3 ad.	2 tad.	94
3	Marion Co., Mo.	39°52'N-91°32'W	18 tad.		100
4	Brown Co., Ill.	39°53'N-90°51'W	18 tad. 1 egg	6 tad.	77
5	Morgan Co., Ill.	39°48'N-90°28'W	40 tad. 1 egg	6 tad.	88
6	Morgan Co., Ill.	39°46'N-90°19'W	11 tad. 1 egg 1 hybrid ad. 1 tape recording	5 tad. 1 ad.	63
7	Macoupin Co., Ill.	39°11'N-89°58'W	28 tad. 2 ad. 2 tape recordings	18 tad. 4 ad. 1 egg	56
8	Macoupin Co., Ill.	39°11'N-89°58'W	38 tad.		100
9	Macoupin Co., Ill.	39°11'N-89°58'W	9 egg	4 egg	69
10	Madison Co., Ill.	38°55'N-89°58'W		20 egg	0
11	Madison Co., Ill.	38°53'N-89°53'W	20 tad.	20 tad. 3 ad.	47

TABLE 1 continued

No.	Locality	Latitude-Longitude	R. blairi	R. utricularia	% R. blairi
12	Madison Co., Ill.	38°51'N-90°03'W	20 tad. 2 egg		100
13	Madison Co., Ill.	38°50'N-90°00'W	1 ad.	6 juv.	14
14	Madison Co., Ill.	38°49'N-89°59'W	3 ad. 2 egg 1 tape recording	5 ad. 22 egg	11
15	Madison Co., Ill.	38°49'N-90°03'W	4 ad. 52 tad. 2 egg 1 hybrid egg	4 ad. 7 tad. 3 egg	77
16	Madison Co., Ill.	38°48'N-89°59'W	1 ad.	6 ad. 1 egg	11
17	Madison Co., Ill.	38°47'N-90°00'W		20 tad. 4 egg	0
18	St. Louis Co., Mo.	38°31'N-90°33'W	21 tad. 7 hybrid tad. 2 tape recordings	120 tad. 1 ad.	16
19	St. Louis Co., Mo.	38°31'N-90°33'W		20 tad.	0
20	St. Louis Co., Mo.	38°31'N-90°33'W	4 tad. 3 hybrid tad.	28 tad.	16
21	St. Louis Co., Mo.	38°31'N-90°33'W		14 tad.	0
22	St. Louis Co., Mo.	38°31'N-90°33'W		20 tad.	0

TABLE 1 continued.

No.	Locality	Latitude-Longitude	R. blairi	R. utricularia	% R. blairi
23	St. Clair Co., Ill.	38°31'N-90°10'W		2 ad.	0
24	St. Clair Co., Ill.	38°29'N-90°02'W		1 egg	0
25	St. Clair Co., Ill.	38°28'N-90°09'W		1 ad.	0
26	St. Clair Co., Ill.	38°27'N-90°00'W	3 egg		100
27	Franklin Co., Mo.	38°28'N-90°52'W		3 egg	0
28	Franklin Co., Mo.	38°26'N-90°55'W	11 tad.	2 tad.	85
29	St. Clair Co., Ill.	38°26'N-90°05'W	1 ad.		100
30	St. Clair Co., Ill.	38°25'N-90°06'W		1 egg	0
31	St. Clair Co., Ill.	38°24'N-90°01'W		1 ad.	0
32	Hickory Co., Mo.	37°52'N-90°16'W		2 egg	0
33	Perry Co., Mo.	37°51'N-89°50'W	1 ad.	3 ad.	25
34	Perry Co., Mo.	37°48'N-89°51'W	7 egg 1 hybrid egg	3 egg	68
35	Perry Co., Mo.	37°40'N-89°56'W		3 egg	0
36	Madison Co., Mo.	37°35'N-90°10'W	1 egg	9 egg	10

TABLE 1 continued

No.	Locality	Latitude-Longitude	R. blairi	R. utricularia	% R. blairi
37	Madison Co., Mo.	37°34'N-90°13'W		2 egg	0
38	Madison Co., Mo.	37°34'N-90°12'W		3 egg	0
39	Madison Co., Mo.	37°34'N-90°13'W		6 egg	0

posteriorly to a point just short of midway over the base of the thigh" (Mecham, 1968:39); 2) snout spot--A large dark spot may be situated anterior to the orbit. Occasionally only a small elongate splotch of pigment is present. A ratio was made of the largest diameter of the snout spot to the anterior-posterior diameter of the eye; 3) vocal sacs--The external vocal sacs of the males examined were either small, inconspicuous structures without posterior projections or large balloon-like sacs with posterior projections. Sonagrams made from tape recordings (loc. no. 7) of calling males were analyzed for the characteristics of the vocalizations.

RESULTS

Three LDH phenotypes were present in the study area. Table 2 compares the morphological characteristics of adult frogs of the three LDH types. Two audibly different mating calls were heard in the area. At locality no. 7 on September 14, 1973, the calls of two males were tape-recorded and the frogs captured. The water temperature was 20°C. One male was R. blairi by morphology and the characteristics of its call were similar to those published by Brown and Brown (1972) and Littlejohn and Oldham (1968) for that frog. The pulse rate of its call was 5.0 per second; the duration of the call was 0.65 second; the duration of a pulse was 30.0 milliseconds. Electrophoresis showed that the first male had the slowest migrating LDH pattern of the three found in the study area (PIP I). The other male possessed R. utricularia morphology and the fastest migrating LDH pattern (PIP III). The pulse rate of its call was 12.4 per second; the duration was 0.55 second; the pulse duration was 39.0 milliseconds. These call characteristics are comparable to those published for the southern leopard frog (Brown and Brown, 1972; Littlejohn and Oldham, 1968). The third LDH pattern was intermediate in speed of migration. This phenotype was the same as that shown by laboratory produced hybrids (R. blairi X R. utricularia) (Axtell, 1974). Since morphology and vocalizations of adults correspond to LDH phenotype and since genetic studies with leopard frogs (Axtell, 1974; Salthe, 1969; Wright, 1968; Wright and Moyer, 1968; Wright and Subtelny, 1971) have shown that eggs and tadpoles

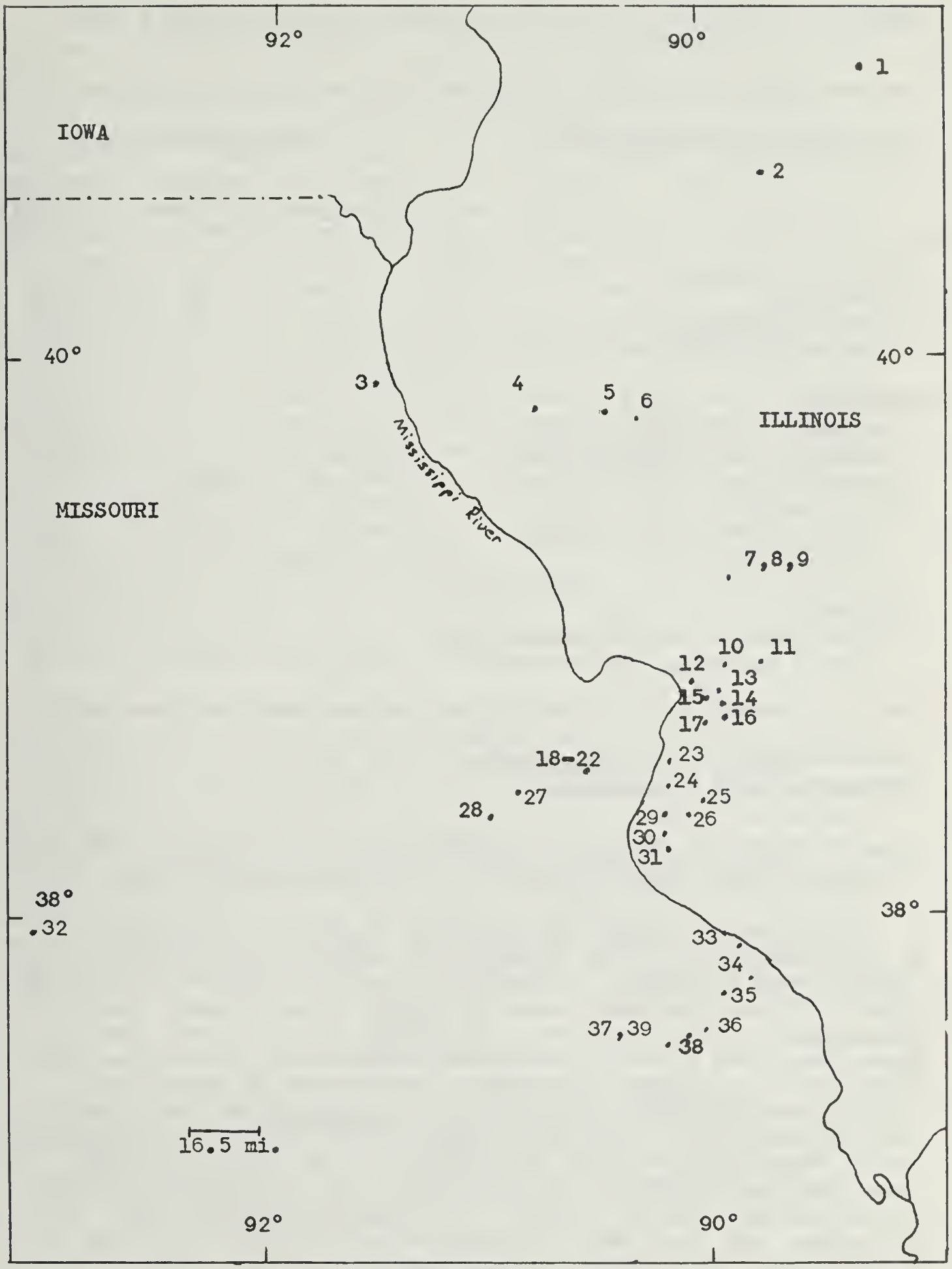

Figure 1--Map of Collection Sites. The numbers correspond to the localities listed in Table 1 and discussed in the text.

TABLE 2. Comparative Morphology of Leopard Frogs with PIP I and PIP III LDH

Morphologic Character	LDH Phenotype		
	PIP I (N = 27)	PIP III (N = 37)	Hybrid (N = 1)
Dorsolateral Ridges			
Complete*	2	33	-
Broken by dashes	3	4	1
Broken and deflected medially**	22	0	-
Snout Spot			
Number of individuals with**	25	5	1
Number of individuals without*	2	32	-
Size of spot to eye diameter (range)	.36-.66	.16-.33	.37
Size of spot to eye diameter (average)	.55	.23	.37
Vocal Sacs			
With posterior projections*	0	26	-
Without posterior projections**	10	1	1

*Characteristic of R. utricularia

**Characteristic of R. blairi

inherit their LDH pattern, it is now possible to use the LDH phenotype to assign species identification to egg clutches and tadpoles.

Thirty-seven adults, 288 tadpoles, and 88 egg clutches of R. utricularia were found. Twenty-seven adults, 308 tadpoles, and 29 clutches were R. blairi. One adult, 10 tadpoles, and two clutches of hybrid LDH phenotype were found. R. blairi is more common than R. utricularia in populations north of Madison Co., Illinois. Table 1 shows that these northern populations consistently contain more than fifty percent R. blairi individuals. Populations in Madison Co., Illinois usually show a majority of R. utricularia with the exception of two populations (12, 15) located along an old oxbow of the Mississippi River. Three ponds (26, 28, 34) with over fifty percent R. blairi were found south of Madison Co., Illinois. No. 26 is located at the top of a steep bluff at the edge. The others are located above the floodplain and half way up gradual slopes. High proportions of R. utricularia were found in populations located away from the rivers in the southern portion of the study area.

Extent of Sympatry--Adult R. blairi and R. utricularia occurred together in choruses of calling males in the spring of 1973 (14, 15, 33), the fall of 1973 (6, 7) and the spring of 1974 (13). Adults and young of both species were collected sympatrically from 40°37'N Latitude in Peoria Co., Illinois, south to 37°51'N Latitude in Perry Co., Missouri. Tadpoles or eggs of both LDH phenotypes inhabited ponds from Peoria Co., Illinois to Madison Co., Missouri. This is a north-south distance of approximately 350 km. Tadpoles or metamorphosing juveniles were collected from 18 breeding ponds. Tadpoles of both species were found in ten of the ponds; R. blairi tadpoles were found in four; R. utricularia tadpoles were found in four. Location no. 11 contained R. blairi tadpoles early in the summer of 1972 and R. utricularia tadpoles the following February. Hybrid tadpoles occurred at Washington University Tyson Center Teardrop and Pippins Ponds (18, 20). At five ponds (9, 14, 15, 34, 36) I collected recently-laid R. blairi and R. utricularia egg masses on the same day. Of those 32 sympatric clutches, 16 were R. blairi, 14 were R. utricularia and two were hybrid. The hybrid eggs were found near Perryville, Missouri (34) and Edwardsville, Illinois (15). In contrast to the above five ponds where both species laid eggs, 17 other ponds contained the eggs of one species only. Twelve ponds contained only R. utricularia clutches. Those 47 clutches represented 53% of the number (N=88) laid by R. utricularia. Five ponds contained only R. blairi clutches. Those eight egg clutches, whose hatchlings would not have to compete with R. utricularia hatchlings, made up 28% of the clutches laid by R. blairi (N=29).

Extent of Hybridization--The predictions of the Hardy-Weinberg Law were tested on two populations of tadpoles (18, 20) and two samples of egg clutches (15, 34), where eggs or tadpoles of both R. blairi and R. utricularia were present at the same time. Data for both species and their hybrid are presented in Table 3. For both tadpole populations, hybrids were not present in the proportions predicted by the Hardy-Weinberg Law ($P<.005$). When the two ponds with hybrid eggs were analyzed individually the P values were not significant. The sample size was small in both cases (N=6, 7). A single adult was found with the intermediate LDH phenotype. This male (S-V 68 mm) was collected in Morgan Co., Illinois (6) on 24 August 1973. Its morphology is given in Table 2.

DISCUSSION

Adults of R. blairi and R. utricularia were previously distinguished by morphology and breeding call characteristics. This study shows that the LDH pattern corresponds to those traits. It is now possible to ascertain the species identity of tadpoles and egg clutches. This finding will facilitate field studies of the interactions between the species in their larval stages.

This study shows considerable overlap between R. blairi and R. utricularia in their use of breeding ponds in the area. In spite of their contact, the two species are not introgressing. Analysis of

TABLE 3. Genotypic Proportions and Allele Frequencies for HLDH Allotypes in Leopard Frogs

Loc. No.	No. of Individuals	Genotype: Observed (expected)			Allele Frequencies	
		R. blairi	R. utricularia	Hybrid	R. blairi	R. utricularia
18	136 tadpoles	21(4.41)	108(91.45)	7(40.15)	18	82
		$X^2 = 92.98(2)$	P<.005			
20	35 tadpoles	4(0.86)	28(24.86)	3(9.27)	16	84
		$X^2 = 16.10(2)$	P<.005			
15	6 clutches	2(1.04)	3(2.04)	1(2.92)	42	58
		$X^2 = 2.6(2)$	P<.50			
34	7 clutches	3(1.75)	3(1.75)	1(3.50)	50	50
		$X^2 = 3.5(2)$	P<.25			

the observed and expected numbers of each genotype in populations of of tadpoles and eggs where both species are present showed a deficit of hybrid types. Hybridization may be prevented by the differing breeding calls. This study suggests that the two species are reproductively isolated. Fifty-four percent of the ponds where eggs were collected contained eggs of R. utricularia only; 23 percent had eggs of R. blairi only; 23 percent had both. This indicates partial distributional and possibly ecological separation of the two species. There is also partial temporal isolation acting to reduce chances of hybridization. Axtell (1974) showed that R. utricularia deposited eggs approximately ten days before R. blairi in the spring of 1973.

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ADDITIONS TO THE VASCULAR FLORA OF GREENE COUNTY, ILLINOIS

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ABSTRACT

One hundred and two previously unrecorded species of vascular plants for Greene County, Illinois are reported.

The vascular plant records reported in this paper for Greene County, Illinois, are the result of collections made from the summer of 1973 through the fall of 1975. Dolbeare (1973), Dolbeare and Ebinger (1974), Jones and Fuller (1955), Mohlenbrock (1967, 1970a, 1970b, 1972, 1973), Sheviak (1974) and Winterringer and Evers (1960) have already recorded 545 species of vascular plants for the county and listed in this report are an additional 102 species. The species reported represent 44 families (1 fern, 37 dicot, 6 monocot). Of these species one is a fern, 13 are monocots and 88 are dicots, the latter group comprised of 80 herbaceous and 8 woody species. Of these 102 species reported, 66 (64.7%) are native and 36 (35.3%) are aliens. Most of the aliens were collected from old fields or disturbed ground, indicating that these non-native disturbophytes comprise an ever increasing part of the county flora, replacing native plants whose habitats are being destroyed primarily by agricultural practices.

Two species in the following list merit comment on their occurrence. Rudbeckia amplexicaulis Vahl is noted by Jones (1963) as rarely adventive from western United States, by Jones and Fuller (1955) as occurring along railroads in two counties (Cook in 1893 and Jackson in 1951), and by Kibbe (1952) (without habitat) as questionably occurring in Hancock County. The Greene County specimens were collected from a small group of plants at the edge of a field. The initial collection of Dipsacus laciniatus L. was made from a large population which had spread several hundred feet from a cemetery. A later collection (Coll. Nos. 491, 492, 493) of D. laciniatus was from a roadside approximately three miles from the nearest cemetery. These plants were growing for a distance of about 100 feet along the edge of a gravel road and it is suggested that seeds may have been dropped from a passing vehicle. Although this species can not be considered naturalized it is certainly spontaneous and growing quite successfully even though some of the plants were dwarfed probably due to mowing and the gravelly soil.

In the following list, each of the 102 species listed is followed by a habitat notation and the collector's name and collection number. Nomenclature follows that of Jones (1963). An asterisk preceeding the name indicates the species as an alien based on Myers (1972). Floating and submerged hydrophyte voucher specimens are deposited in the W.I.U. Kibbe Life Science Station Herbarium (WARK) and all other voucher specimens are deposited in the Western Illinois University Herbarium (MWI).

FERNS

SALVINIACEAE

Azolla mexicana Presl. Ditch; Henry and Scott 398.

DICOTYLEDONEAE

ACANTHACEAE

Ruellia humilis Nutt. Moist woods; Scott 161.

AIZOACEAE

*Mollugo verticillata L. Open waste ground; Henry and Scott 278.

APOCYNACEAE

Apocynum sibiricum Jacq. Roadside; Henry and Scott 275.

ASCLEPIADACEAE

Ampelamus albidus (Nutt.) Britt. Field; Henry and Scott 377.

Asclepias incarnata L. Swamp; Henry and Scott 342.

Asclepias syriaca L. Roadside ditch; Henry and Scott 399.

BETULACEAE

Corylus americana Walt. Woods; Scott 140.

BIGNONIACEAE

Campsis radicans (L.) Seem. Roadside ditch; Henry and Scott 375.

BORAGINACEAE

Hackelia virginiana (L.) I.M. Johnst. Open woods; Scott 78.

CANNABINACEAE

*Cannabis sativa L. Disturbed field near fence; Scott 200.

CAPPARIDACEAE

Polanisia dodecandra (L.) DC. By railroad; Henry and Scott 297.

CAPRIFOLIACEAE

Sambucus canadensis L. Fenced border of woods; Scott 119.

CARYOPHYLLACEAE

*Arenaria serpyllifolia L. By railroad; Henry and Scott 285.

*Lychnis alba Mill. By roadside ditch; Henry and Scott 246.

Silene stellata (L.) Ait.f. Woods; Scott 95.

CERATOPHYLLACEAE

Ceratophyllum demersum L. Swamp; Henry and Scott 425.

CHENOPODIACEAE

Chenopodium boscianum Moq. Old field; Henry and Scott 390.

*Salsola pestifer A. Nels. Railroad; Henry and Scott 393.

CISTACEAE

Lechea tenuifolia Michx. Old field; Henry and Scott 338.

COMPOSITAE

*Anthemis cotula L. Edge of woods; Scott 12.

Aster novae-angliae L. Swamp; Henry and Scott 300.

Bidens frondosa L. Field; Henry and Scott 424.

Bidens polylepis Blake. Along ditch; Henry and Scott 476.

Boltonia recognita (Fern. and Grisc.) G.N. Jones. Wet ditch; Henry and Scott 487, 488.

*Carduus nutans L. Waste ground; Henry and Scott 414.

*Chrysanthemum leucanthemum L. Old field; Henry and Scott 381.

*Cirsium vulgare (Savi) Tenore. Disturbed ground, border of woods; Scott 100.

Eclipta alba (L.) Hassk. Swamp; Henry and Scott 299.

Eupatorium perfoliatum L. Swamp; Henry and Scott 347, 357.

Eupatorium purpureum L. Open woods; Scott 129.

*Galinsoga ciliata (Raf.) Blake. Old field; Henry and Scott 431.

*Helianthus annuus L. By railroad; Henry and Scott 511, 512.

*Matricaria matricarioides (Less.) Porter. Waste ground; Henry and Scott 413.

*Rudbeckia amplexicaulis Vahl. Edge of field; Henry and Scott 250.

Rudbeckia laciniata L. Floodplain; Henry and Scott 489, 490.

Rudbeckia triloba L. Swamp; Henry and Scott 340.

Solidago nemoralis Ait. Light open woods; Henry and Scott 503.

Solidago ulmifolia Muhl. Open light woods; Henry and Scott 519, 520.

*Sonchus oleraceus L. Old field; Henry and Scott 366.

*Tragopogon dubius Scop. Roadside; Henry and Scott 394.

Verbesina helianthoides Michx. Edge of woods; Henry and Scott 229.

Xanthium commune Britt. Disturbed ground, edge of woods; Scott 169.

CRUCIFERAE

*Brassica nigra (L.) Koch. Roadside; Henry and Scott 395.

*Lepidium campestre (L.) R.Br. By railroad; Henry and Scott 296.

*Rorippa sylvestris (L.) Besser. By railroad; Henry and Scott 203.

CUCURBITACEAE

Sicyos angulatus L. Illinois River floodplain; Henry and Scott 276.

DIPSACACEAE

*Dipsacus laciniatus L. Railroad across from cemetery; Henry and Scott 332.

EUPHORBIACEAE

Chamaesyce supina (Raf.) Moldenke. Railroad; Henry and Scott 358.

Croton monanthogynus Michx. By railroad; Henry and Scott 287.

HYPERICACEAE

Hypericum punctatum Lam. Woods along creek; Scott 122.

Hypericum sphaerocarpum Michx. By roadside; Henry and Scott 204, 205.

LABIATAE

Blephilia hirsuta (Pursh.) Benth. Edge of woods; Henry and Scott 259.

*Nepeta cataria L. Roadside; Henry and Scott 209.

Pycnanthemum flexuosum (Walt.) BSP. Open woods; Scott 184.

LEGUMINOSAE

Apios americana Medic. Waste ground; Henry and Scott 231.

Baptisia leucantha T.&G. Roadside; Henry and Scott 227, 228.

*Lespedeza stipulacea Maxim. Along ditch by road; Henry and Scott 522.

*Vicia dasycarpa Ten. By railroad; Henry and Scott 242.

LOBELIACEAE

Lobelia cardinalis L. Lowland; Henry and Scott 521.

LYTHRACEAE

Cuphea petiolata (L.) Koehne. Woods; Scott 189.

MALVACEAE

*Abutilon theophrasti Medic. Field; Henry and Scott 428.

*Hibiscus trionum L. Old field; Henry and Scott 513, 514.

MORACEAE

*Morus alba L. Field; Henry and Scott 421.

NYCTAGINACEAE

Mirabilis nyctaginea (Michx.) MacM. Railroad; Henry and Scott 363.

ONAGRACEAE

Circaea latifolia Hill. Rich woods; Scott 32.

Jussiaea repens L. Ditch; Henry and Scott 361.

POLYGONACEAE

*Polygonum aviculare L. Field; Henry and Scott 420.

*Rumex crispus L. Old field; Henry and Scott 265.

RANUNCULACEAE

Anemone virginiana L. Rich woods; Scott 30.

Ranunculus sceleratus L. By ditch; Henry and Scott 238.

ROSACEAE

Agrimonia parviflora Ait. Old field; Henry and Scott 369.

Malus ioensis (Wood) Britt. Edge of woods; Henry and Scott 270.

*Potentilla recta L. Railroad; Henry and Scott 372.

*Rosa multiflora Thunb. Scattered throughout woods; Scott 177.

Rubus allegheniensis Porter. Open wooded hillside; Scott 64.

SCROPHULARIACEAE

*Chaenorrhinum minus (L.) Lange. By railroad; Henry and Scott 298.

Gerardia tenuifolia Vahl. Old field; Henry and Scott 388.

*Linaria vulgaris Hill. By railroad; Henry and Scott 224.

Mimulus ringens L. Swamp; Henry and Scott 349.

*Verbascum blattaria L. By railroad; Henry and Scott 292.

SIMARUBIACEAE

*Ailanthus altissima (Mill.) Swingle. Fence row; Henry and Scott 406.

SOLANACEAE

Solanum nigrum L. Field; Henry and Scott 422.

UNBELLIFERAE

Chaerophyllum procumbens (L.) Crantz. Old woods; Henry and Scott 320.

Cryptotaenia canadensis (L.) DC. Woods; Scott 195.

Osmorhiza claytonii (Michx.) Clarke. Woods; Henry and Scott 308.

URTICACEAE

Boehmeria cylindrica (L.) Sw. Old field; Henry and Scott 392.

Urtica gracilis Ait. Roadside ditch; Henry and Scott 282.

ZYGOPHYLLACEAE

*Tribulus terrestris L. Railroad; Henry and Scott 370.

MONOCOTYLEDONEAE
CYPERACEAE

Carex normalis Mack. Roadside ditch; Henry and Scott 452.

Eleocharis calva Torr. Ditch; Henry and Scott 458.

Scirpus acutus Muhl. By ditch; Henry and Scott 462.

GRAMINEAE

Calamagrostis canadensis (Michx.) Beauv. Ditch by road; Henry and Scott 442.

Muhlenbergia frondosa (Poir.) Fern. By railroad; Henry and Scott 470.

Paspalum geminum Nash. Along ditch; Henry and Scott 469.

Phalaris arundinacea L. Roadside ditch; Henry and Scott 445.

LEMNACEAE

Lemna minor L. Swamp; Henry and Scott 337.

Wolffia columbiana Karst. Swamp; Henry and Scott 335.

LILIACEAE

*Hemerocallis fulva L. Edge of road; Henry and Scott 253.

ORCHIDACEAE

Liparis lilifolia (L.) Rich. Wooded hillside; Scott 182.

POTAMOGETONACEAE

Potamogeton americanus C.&S. Swamp; Henry and Scott 427.

*Potamogeton crispus L. Submerged in ditch; Henry and Scott 254.

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A COILED NAUTILOID FAUNA FROM THE MATTOON FORMATION (PENNSYLVANIAN) OF ILLINOIS

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ABSTRACT

A large cephalopod fauna has been collected from the Shumway Limestone Member of the Mattoon Formation (Virgilian: Pennsylvanian) from Effingham Co., Illinois. The coiled nautiloids include eleven species ten of which are considered in the present paper. Seven new species are described including Tainoceras sexlineatum n. sp., Metacoceras copei n. sp., Domatoceras wortheni n. sp., D. mattoonense n. sp., Stearoceras involutum n. sp., Solenochilus shumwayense n. sp., and Ephippioceras moinellae n. sp. Previously described species included in the fauna are Tainoceras monilifer Miller, Dunbar and Condra and Liroceras liratum (Girty). An unidentified specimen is tentatively referred to Metacoceras. The ontogeny of Tainoceras monilifer is described in detail for the first time and an ancestral group of Metacoceras is suggested. Tainoceras murrayi formerly considered a valid species is shown to be a specimen of T. monilifer.

INTRODUCTION

Except for Illinois, the nautiloid faunas of the Pennsylvanian Period of the Mid-Continent states have been studied in some detail (Miller, Dunbar and Condra, 1933; Miller and Owen, 1934). Unklesbay (1962) also described Pennsylvanian nautiloids from Oklahoma and the nautiloids of the Pennsylvanian in Ohio have been extensively studied (Miller and Unklesbay, 1942 and 1947; Sturgeon, 1946; Sturgeon and Miller, 1948; Murphy, 1970 and 1974). Except for the 19th century descriptions of a few species of nautiloids by McChesney, Meek and Worthen information about Pennsylvanian nautiloids of Illinois is very incomplete and represents a significant gap in our knowledge about the distribution and character of nautiloid faunas in the Mid-Continent. The present paper describes the coiled nautiloids from a large cephalopod fauna (Table 1) from the Mattoon Formation of Illinois.

The type localities of all newly described species are at the type locality of the Shumway Limestone Member at SE1/4 SE1/4 SW1/4, sec. 26, T.9N., R.5E., Effingham Quadrangle, Effingham Co., Ill. All specimens were collected in the lower bed of the Shumway Limestone Member. Catalog numbers unless otherwise noted are those of the invertebrate paleontological

TABLE 1. The cephalopods of the Shumway Limestone Member. * denotes species that are described in this report.

Mooreoceras sp.
Brachycycloceras normale Miller, Dunbar and Condra
Brachycycloceras sp.
Tainoceras monilifer Miller, Dunbar and Condra *
T. sexlineatum n. sp. *
Metacoceras copei n. sp. *
Metacoceras sp. *
Cooperoceras n. sp. (Tucker, in press)
Domatoceras wortheni n. sp. *
D. mattoonense n. sp. *
Stearoceras involutum n. sp. *
Solenochilus shumwayense n. sp. *
Liroceras liratum (Girty) *
Ephippioceras moinellae n. sp. *
Goniolaboceras sp.
Eoasinites sp.

collections of the Field Museum of Natural History, Chicago where all types are deposited. Although most of the specimens reported here were collected by the author over a period of years, D. Moll and G. Paukstis made significant contributions. R. Hart, G. Paukstis and R. Weigel made laboratory and darkroom equipment available. I thank L. Brown, R. Funk and D. Moll for reading the manuscript. The University of Iowa Geology Department and the Carnegie Museum made specimens available.

STRATIGRAPHIC AND FAUNAL SUMMARY

The Shumway Cyclothem which includes the Shumway Limestone Member was described by Kosanke et al. (1960). It is probably Lower Virgilian in age and roughly correlates with the Lawrence Shale or Iatan Limestone of the Mid-Continent and presumably the Upper Conemaugh of Ohio (Kosanke et al., 1960). The lower bed of the Shumway Limestone is a blue-grey to grey, fine grained, impure limestone that weathers reddish to buff in color. Associated with the limestone are some terrigenous sediments and occasionally logs are found preserved in it. The most common and best preserved invertebrates are the productid brachiopods. These are for the most part unsorted and are generally articulated. Pedunculate brachiopods are much rarer. The nature of the brachiopod fauna suggests that the Shumway Limestone was a carbonate bank similar to Watkins' (1974) Lissomarginifera association although differing in species composition. The nautiloids of the Shumway Limestone are similar to those found in other Upper Pennsylvanian units in the United States. Cooperoceras and Stearoceras are characteristic of Permian and Pennsylvanian beds of the southwest and their occurrence in the Shumway Limestone suggests faunal connections with the southwestern United States.

SYSTEMATIC PALEONTOLOGY

Order Nautilida Agassiz, 1847
Family Tainoceratidae Hyatt, 1883
Genus Tainoceras Hyatt, 1883
Tainoceras monilifer Miller, Dunbar and Condra, 1933
Pl. 1, fig. 7, text fig. 1.

1933. Tainoceras monilifer Miller, Dunbar and Condra, Nebraska Geol. Survey, Bull. 9, 2d ser., p. 148-151, Pl. 10, figs. 1-5.
1942. Tainoceras monilifer Miller and Unklesbay, Carnegie Museum Annals, 29, p. 142-143, Pl. 4, fig. 3 (not 1-2).
1942. Tainoceras murrayi Miller and Unklesbay, Jour. Paleontology, 16, p. 729, Pl. 114, figs. 2,3.
1962. Tainoceras monilifer Unklesbay, Oklahoma Geol. Survey, Bull. 96, p. 31-33, Pl. 2, fig. 10.
1962. Tainoceras murrayi Unklesbay, Oklahoma Geol. Survey, Bull. 96, p. 33, Pl. 2, fig. 11,12.

Material. 47 specimens (PE 27971-PE 28017) mostly testiferous fragments were collected.

Description. The general features of this species were described by Miller, Dunbar and Condra (1933); only details that they could not observe are considered here. Two specimens have the earliest whorls preserved and show that shells 55 mm in diameter consisted of two volutions. Mature specimens (85-95 mm in diameter) must have consisted of about 3.5 volutions. The umbilicus is large with an umbilical perforation of 2-6 mm in diameter. The ventral nodes abruptly appear at a diameter of 28 mm or after about 1.5 volutions. They are staggered and remain so with few exceptions until they disappear at a ventral width of 37.2 mm (range = 32-43 mm) or a diameter of at least 85 mm. The left row of ventral nodes appears first in the two specimens where this could be observed. The mid-ventral sulcus is present before the ventral nodes are visible. This furrow develops at a diameter of about 25 mm. The first quarter volution is essentially circular in cross section and is unornamented. Lateral plicae that slant apicad from the ventrolateral shoulders appear on the second quarter volution. The plicae become more and more slanted apically as the end of the first volution is approached. The ventrolateral and umbilical ends of the plicae are elevated into nodes during the last quarter of the first volution. The ventrolateral nodes become enlarged very abruptly while the umbilical nodes remain smaller. The plicae become less pronounced mid-laterally by the end of the first volution. Although plicae are detectable upto 1.5 volutions, the nodes are very pronounced and some umbilical nodes are no longer associated with plicae. By two volutions plicae have disappeared except for the swollen areas immediately above each ventrolateral node. Mid-ventrally there is a slight ridge on the internal mold that represents the conchal furrow. The siphuncle is slightly ventrad of center at all stages. The connecting rings are cylindrical and segments of the siphuncle are not expanded within the camerae. The septal necks are orthochoanitic but are slightly more curved dorsally than ventrally.

Discussion. The early ontogeny of T. monilifer is most similar to that seen in Metacoceras species such as M. perelegans. It is likely that Tainoceras evolved from some species of Metacoceras that possessed umbilical nodes rather than those lacking them such as M. cornutum. The holotype of T. murrayi, contrary to the description, was found to have umbilical nodes and is considered a synonym of T. monilifer.

Tainoceras sexlineatum n. sp.
Pl. 1, figs. 4,5.

1942. Tainoceras monilifer Miller and Unklesbay (not Miller, Dunbar and Condra), Carnegie Museum Annals, 29, p. 142-143, Pl. 4, figs. 1-2 (not 3).

Etymology. This species is named for the six lines of nodes that characterize it.

Material. The holotype (PE 27919) and a paratype (PE 27910) were available for study.

Diagnosis. This species is a convolute Tainoceras with umbilical nodes that extend onto the sides of the conch as indistinct ribs, longitudinally elongate to hemispherical ventrolateral nodes that are small and relatively close together, and a subrectangular conch that is wider than high.

Description. The holotype is a poorly preserved partially crushed specimen. The shell, measuring about 46 mm in diameter, is a convolute rapidly expanding nautilicone consisting of at least two whorls. The umbilical diameter is about 1/3 that of the entire shell. At the adoral end of the whorl, the cross section is subrectangular, being wider than high. The conch is widest at the umbilical shoulders. The dorsal impressed zone is about equal in width to that of the umbilical walls. These are very steep, nearly flat, and form distinct umbilical shoulders with the sides of the conch. The lateral walls are flat and nearly parallel though slightly convergent ventrad. The ventrolateral shoulders are narrowly rounded between the ventrolateral nodes. The venter is evenly convex in early stages and becomes flattened in later stages.

The venter has four rows of nodes, one at each of the ventrolateral shoulders and a central pair that divides the venter into three equal parts. The laterally paired ventrolateral nodes are rather narrow and longitudinally elongate. They increase regularly in size and become hemispherical with enlargement of the shell. Where the venter has a width of 7 mm, these nodes are about 5 mm apart from crest to crest. This distance increases to 7 mm where the venter has a width of 14 mm. The ventrolateral nodes are spaced so that the distance between adjacent nodes is less than the length of the preceeding node. The staggered ventral nodes first appear after at least one volution has been completed. At first the nodes are confluent and form two parallel longitudinal ridges which are soon divided into discrete nodes. At first the nodes are longitudinally elongated but later they become more hemispherical in shape. The space between the ventral nodes develops into a mid-ventral sulcus. Each umbilical shoulder bears a row of nodes. These are almost as numerous and as large as the ventrolateral nodes in the first 1.5 whorls. The ventrolateral nodes enlarge more quickly than the umbilical nodes and soon become much larger than the umbilical nodes. Each umbilical node is elongated into a slight ridge that extends toward the venter. The growth lines form a moderately deep hyponomic sinus and a shallow lateral salient. The last two camerae of the phragmocone of the paratype are crowded suggesting it represents a mature individual. The sutures are sinuous with well developed ventral and lateral lobes. The height and width at mid-length of the paratype is 28 mm and 32 mm respectively. The siphuncle was not observed.

Comparison. Miller and Unklesbay (1942, Pl. 4, figs. 1-2) illustrated two specimens identified as T. monilifer. I have examined these and they are not T. monilifer. The ventral nodes of the Conemaugh Tainoceras are only slightly laterally elongated where they disappear. Those of T. monilifer are laterally elongated after the first 1.5 volutions and remain that way until they disappear. Although the Conemaugh specimens are badly distorted they appear to be conspecific with T. sexlineatum. T. nebrascense Miller, Dunbar and Condra and Tainoceras sp. Miller, Dunbar and Condra lack umbilical nodes. T. wyomingense has umbilical nodes but the ventrolateral nodes of that species are much larger at comparable stages than those of T. sexlineatum.

Genus Metacoceras Hyatt, 1883
Metacoceras copei n. sp.

Pl. 1, fig. 6; Pl. 3, figs. 1,2; Pl. 4, fig. 3.

Etymology. This species is named for Edward Drinker Cope, vertebrate paleontologist and herpetologist.

Material. The holotype (PE 27920), a fragment of about half a whorl, and paratypes (PE 27921-PE 27923, PE 27949, PE 27961-PE 27969) were collected.

Diagnosis. This species is a depressed Metacoceras with ventrolateral nodes that have knob-like distal ends and that have lateral extensions of the nodes running almost to the umbilical shoulder which is non-nodose.

Description. The evolute conch consists of about three whorls. The umbilicus is perforate and about half the diameter of the conch. The nearly circular umbilical perforation is about 4 mm wide. The living chamber makes up at least half a whorl. The cross section of the whorl is variable at different stages of growth. Where the venter is 5 mm wide the whorl is elliptical in cross section. The umbilical shoulders are apparent but rounded where the venter is 7 mm wide or after a little more than half a volution. At this stage the conch is subtrapezoidal in cross section being widest at the venter. After 1.5-2 whorls the cross section is depressed subrectangular being wider than high. The dorsum is slightly impressed. The venter is evenly convex and about equal in width to the umbilical shoulders. The ventrolateral and umbilical shoulders are rounded. The lateral zones are flattened though slightly convex. After 2-2.5 whorls the conch has a width of 28 mm and a height of 15 mm. The whorl is widest slightly ventrad of the umbilical shoulders. The venter is flattened and has a slight mid-ventral sulcus developed. The lateral zones are flat but the ventrolateral and umbilical shoulders are rounded. The umbilical walls are only slightly convex and meet the dorsum at an acute angle.

The ornamentation consists of laterally paired ventrolateral nodes that extend onto the sides of the conch as distinct ribs. Umbilical nodes are absent throughout. On the first half volution the conch has pronounced transverse lirae that may be homologous to growth lines. These are greatly reduced at the end of the first half volution where the ventrolateral nodes appear. The ventrolateral nodes are associated with ribs at all growth stages observed. The nodes have enlarged knob-like distal ends that become apparent after one whorl has been completed. The ventrolateral nodes of the holotype are reduced in size at the adoral end and are irregularly spaced. This may be due to injury or to mature modification of the nodes. The exact cause could not be determined

as the nodes on the other side are not preserved and none of the paratypes are as large as the holotype. Growth lines show that a deep hyponomic sinus was present along with slight lateral salients.

The sutures are somewhat sinuous with a slight ventral lobe bordered by ventrolateral saddles, lateral lobes and umbilical saddles. There is a slight dorsal lobe but no annular process. The siphuncle is variable in position depending on growth stage. In the first half volution it is 0.6 mm in diameter and almost in contact with the venter. By the time 1.5 volutions have been completed the siphuncle has moved dorsally and is about central in position. The internal structure of the siphuncle is not known.

Comparison. This species is most similar to Metacoceras cornutum Girty. The position of the siphuncle is not known to vary in that species. M. cornutum has ventrolateral nodes that are much larger and elongate than those of M. copei. Also M. cornutum does not retain lateral extensions of the nodes as does M. copei. M. dubium Hyatt resembles M. copei in cross section. The internal mold of M. dubium lacks lateral extensions of the ventrolateral nodes. These may be easily seen on the internal mold of M. copei.

Discussion. Murphy (1970) with some question included the small paratype of M. cornutum Girty in the synonomy of his M. mcchesneyi. This is certainly incorrect because Girty's figure (1915, Pl. 29, fig. 4) is at odds with Murphy's (1970) description of M. mcchesneyi. Murphy pointed out that M. mcchesneyi has angular umbilical shoulders and lacks well developed ventrolateral nodes and their lateral extensions at an early stage. The specimen figured by Girty has angular umbilical shoulders but it also has well developed ventrolateral nodes and their lateral extensions on the first whorl. Girty's paratype more closely resembles M. sangamonense than any other species.

(?) Metacoceras sp.
Pl.2, fig. 2; Pl. 4, fig. 2.

Material. One poorly preserved specimen (PE 27970) was collected.

Comparison. The specimen is too poorly preserved to describe but it may be differentiated from all other species of Tainoceratidae of the fauna by the nature of its ventrolateral nodes. These do not closely resemble those of equal sized M. copei nor of young Tainoceras.

Family Grypoceratidae Hyatt in Zittel, 1900
Genus Domatoceras Hyatt, 1891
Domatoceras wortheni n. sp.
Pl. 1, figs. 1-3; Pl.2, fig. 1; Pl. 4, fig. 1.

Etymology. This species is named for A. H. Worthen, State Geologist for Illinois from 1858-1888.

Material. The holotype (PE 27951) though fragmentary shows the features of the species. The paratypes (PE 27924-PE 27936, PE 27938-PE 27948, PE 27950, PE 27952-PE 27955) were also available.

Diagnosis. This species is a slightly convolute Domatoceras with convergent, nearly flat sides, flat to slightly convex venter, moderately elongate ventrolateral nodes that are interconnected by a persistent carina on the last volution.

Description. The evolute conch is subdiscoidal with 3.5-4 whorls;

the maximum observed diameter is 117 mm. The diameter of the umbilicus is about 1/3 the diameter of the entire shell. The umbilical perforation varies from 4-7 mm in diameter. The whorl section is compressed subtrapezoidal, higher than wide though it is variable at different growth stages. The cross section is essentially circular in the first half volution. Lateral zones appear at a width of 8 mm or after about 3/4 volution. At this stage the venter is evenly convex on both the internal mold and the test. Because the width of the whorl increases more rapidly at the dorsum than the venter, beyond a width of 10 mm the flanks become convergent ventrad. The flanks are evenly convex except for a flattened zone immediately above the ventrolateral carina. Beyond a height of 20 mm the sides are flattened. The impressed zone is present at a height of 12 mm. The venter is evenly convex in young stages but becomes nearly flat in later whorls. The ventrolateral carinae, developed at a height of 8 mm, remain prominent at all growth stages. The carinae develop into a series of longitudinally elongated nodes at a height of 28 mm or after about 3 whorls have been completed. The nodes are closely spaced with the space between adjacent nodes smaller than the length of the preceeding node. At this stage the ventrolateral nodes are present on the internal mold and are about as numerous as they are on the test. The ventrolateral carinae are persistent and follow the lateral edge of the venter both between and over the nodes making the venter look concave. The ventral surfaces of the nodes have marked concave appearance due to the carinae. Widely spaced ventrolateral nodes are also found on the internal mold where the dorsoventral diameter is about 25 mm but these are not visible on the test due to thickening of the shell between the nodes. The umbilical shoulders are narrowly rounded on the test but more narrowly rounded on the internal mold. Very indistinct umbilical nodes are present on the test of the living chamber of mature specimens. The ventrolateral shoulders of the test are angular and carinate while those of the internal mold are broadly rounded. The umbilical slopes are steep and they meet the dorsum at slightly less than a right angle. Shells of less than two volutions are more angular in general than larger shells. Longitudinal lirae were observed on the venter of large individuals. The growth lines form a deep hyponomic sinus that is bordered on both sides by a lateral salient, and an umbilical sinus. The septal foramen is subcentral in position. The segments of the siphuncle are cylindrical. The septal necks are orthochoanitic in shape though the dorsal ones are more curved than the ventral ones. A conchal furrow was not observed. Up to the first half whorl the suture pattern is essentially transverse to the longitudinal axis of the conch. A few camerae from there the ventral suture is still transverse but slight ventrolateral saddles, lateral lobes, umbilical saddles and a dorsal lobe have appeared. By the end of the first volution a ventral lobe has appeared and the other elements of the suture are more pronounced. The ventral lobe becomes much deeper and more angular in specimens of 2-3 volutions.

Comparison. D. wortheni may be compared to the more subquadratic species of Domatoceras including D. sculptile (Girty), D. umbilicatum Hyatt, D. williamsi Miller and Owen, D. shepherdi Sturgeon and D. walteri Miller and Unklesbay. D. sculptile develops nodes at an earlier stage than does D. wortheni. D. walteri has lateral nodes that are lacking in D. wortheni. D. shepherdi has a lirate internal mold while D. wortheni does not. D. umbilicatum has concave lateral zones while those

of D. wortheni are flat to convex. D. williamsi has pronounced umbilical nodes and lateral crenulations as well as an umbilicus that makes up half of the whorl diameter.

Domatoceras mattoonense n. sp.
Pl. 3, fig. 7.

Etymology. This species is named for the Mattoon Formation.

Material. The holotype (PE 27960) and a paratype (PE 27937) were collected.

Diagnosis. This species is a compressed (height/width = 1.5), convolute Domatoceras with the umbilicus 23% of the diameter of the conch, venter concave on the test and internal mold, septal foramen about central in position.

Description. The compressed convolute subdiscoidal conch has a small perforate umbilicus making up 23% of the diameter of the conch. The whorl section is compressed subtrapezoidal being about 2/3 wide as high. The venter is concave on the internal mold and even more concave on the test due to pronounced ventrolateral carinae. The venter is less than 1/2 as broad as the greatest width of the whorl which is attained a little below the umbilical shoulders. The sides are slightly convex over the upper half of the whorl and become slightly concave toward the venter. The sides converge toward the venter which they meet at sharp ventrolateral angles, both on the test and the internal mold. The umbilical shoulders are broadly rounded on the internal mold and more narrowly rounded on the test. The umbilical walls of the test meet the dorsal impressed zone at acute angles. At the end of the first half whorl, the whorl section is almost circular though slightly higher than wide. Here the height of the whorl is 7 mm and the venter is evenly convex. At 1.5 volutions, the whorl has increased in height to 12 mm, its width is 8 mm and a shallow dorsal impressed zone is present. The venter is flat on the internal mold but concave on the test due to well developed ventrolateral carinae. The venter is about 1/2 as wide as the greatest width of the whorl at the umbilical shoulder. The ventrolateral shoulders of both the test and the internal mold are angular. At this stage the umbilical shoulders are rounded on the internal mold and more narrowly rounded on the test. The narrow, nearly flat umbilical walls are about perpendicular to the plane of coiling. The whorl expands to a height of 30 mm where the body chamber begins. Its impressed zone is 5 mm deep at that point, the greatest width of the whorl is at about 2/3 the distance between the umbilical shoulders and ventrolateral shoulders and is 20 mm. The venter at this stage has a width of 9 mm.

The living chamber is at least 1/3 volution in length. The surface of the internal mold is smooth except for sutures and the periphract which is pleuromyarian in shape. At 1.5 volutions the suture forms a rounded ventral lobe, sharp ventrolateral saddles, broad lateral lobes and a dorsolateral saddle centered near each umbilical shoulder. Since the last camerae of the holotype is somewhat narrower than the preceeding ones, this specimen was probably approaching maturity. The siphuncle is slightly ventrad of center at all stages.

Comparison. D. moorei Miller, Dunbar and Condra and D. mattoonense are compressed to about the same degree. D. mattoonense has a concave venter on the internal mold (flat in D. moorei), has the septal foramen about central in position (ventral in D. moorei) and has an umbilicus making up about 23% of its diameter (16% in D. moorei). D. gardi Murphy

is also similar in degree of involution but is less compressed than D. mattoonense.

Genus Stearoceras Hyatt, 1893
Stearoceras involutum n. sp.
Pl. 4, fig. 4.

Etymology. This species is named for the great degree of involution that characterizes it.

Material. The holotype (PE 27956), a well preserved, partially testiferous mature specimen was available for study.

Diagnosis. This is a relatively compressed, involute Stearoceras which has a width/height ratio of 1.2 at the junction of the living chamber and the phragmocone at maturity, an umbilicus making up about 10% of the diameter and no annular process in at least the outer third volution.

Description. The involute nautiliconic shell makes at least 2.5 and more likely 3.5 volutions and is only slightly depressed. The diameter of the shell measured across the umbilicus is 121 mm. The umbilicus at the same place has a diameter of 13 mm. The whorl is widest at or slightly ventrad of the umbilical shoulders. At the junction of the phragmocone and living chamber, the shell is 78 mm wide and 62 mm high. 1/3 whorl apicad of there the width is 55 mm and the height is 49 mm indicating that the width increases slightly faster than the height. The outer whorl is rounded subtrapezoidal in cross section being only slightly depressed. At maturity, the venter is gently convex while the sides are somewhat flatter. The umbilical walls are steep flattened slopes that form both angular umbilical shoulders and meet the dorsal impressed zone at about 90 degrees. The dorsal impressed zone is deep occupying about 1/6-1/5 the height of the whorl. The cross section is variable with age as the venter and sides are somewhat more convex in inner whorls. The width and height of the whorl are about equal 1.5 whorls apicad of the oral end of the type. The test is thickest at the umbilical shoulders and thins as the venter is approached. It is unornamented except possibly for growth lines which could not be observed on the type.

The camerae are moderately convex apicad and the sutures are only slightly sinuous. There are distinct ventral and lateral lobes that are separated by ventrolateral saddles. Slight saddles center on the umbilical shoulders and the sutures are essentially straight on the umbilical walls. A very shallow lobe is present dorsally. An annular process is not present in at least the outer third volution. The siphuncle is 2-3 mm dorsad of the venter in the inner whorls but moves to about central in position in the outer whorl. It appears to be orthochoanitic and is not greatly expanded within the camerae. The siphuncle is 3 mm in diameter where the shell has a width of 18 mm and is 4 mm wide where the shell is 59 mm wide.

Comparison. The diameter of the umbilicus of S. gibbosum (Hyatt), which is the most involute species previously included in the genus, makes up between 1/3-1/4 the diameter of the shell (Gordon, 1964). S. involutum is much more involute with the diameter of the umbilicus being about 1/10 the diameter of the shell.

Family Solenochilidae Hyatt, 1893
Genus Solenochilus Hyatt, 1893
Solenochilus shumwayense n. sp.

Pl. 1, fig. 8; Pl. 2, fig. 3; Pl. 3, fig. 3.

Etymology. This species is named for the Shumway Limestone Member.

Material. The holotype (PE 27887) and paratypes (PE 27886, PE 27888-PE 27897, PE 27899, PE 27901-PE 27906, PE 27909, PE 27911-PE 27959) were available for study.

Diagnosis. This species is a Solenochilus that is widest ventrad of the umbilical shoulders, has a broad depressed, rapidly expanding involute conch, long dorsolateral spines, rounded sides, lateral concave zones, wide camerae with 3-4 occurring in the space equal to the width of the whorl and relatively straight sutures.

Description. This is a large species that has a depressed nautiliconic conch with a small, deep umbilicus. The umbilicus makes up about 8% of the diameter of the shell. One larger paratype is a fragment of a shell that is estimated to have been at least 180 mm in diameter. The holotype is a fragment of about 3/4 volution from a juvenile shell that probably consisted of close to 2 volutions. The conch is rapidly expanded orad with the width increasing from 35 mm to 50 mm in the space of 27 mm as measured along the venter. The whorls are depressed being about half as high as they are wide. The venter broadly rounds into the more narrowly rounded ventrolateral zones. The umbilical walls are at first convex then become steep flattened slopes that meet the shallow dorsal impressed zone at nearly right angles. The sides are evenly convex in shells that have not surpassed 50 mm in width. Beyong this point revolving concave zones become apparent as do developing apertural spines. Although the concave zones remain indistinct except on very large shells, the sides are considerably flattened beyond a width of 70 mm. The shell is widest about midway between the venter and the umbilical shoulders on shells that

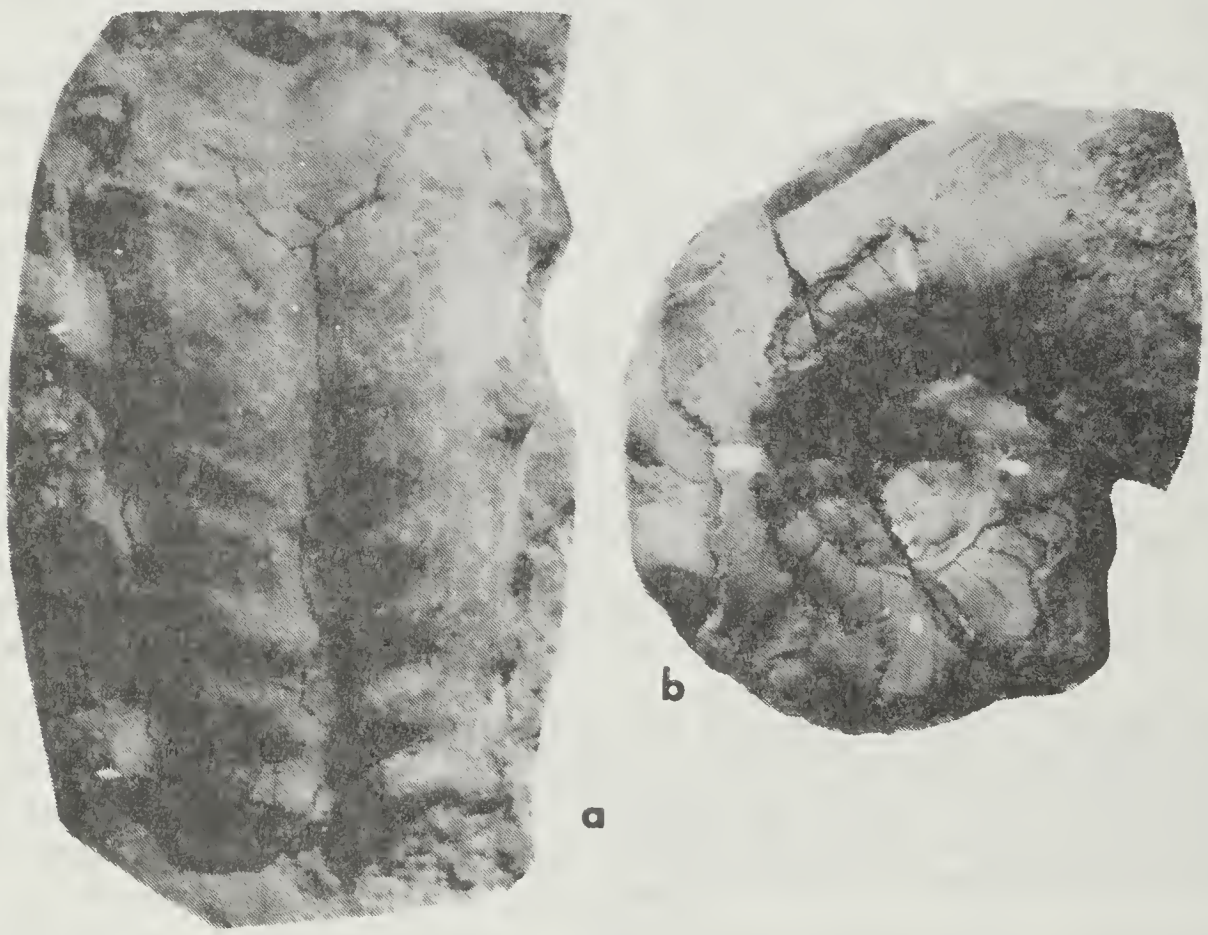

Figure 1. Ventral and lateral views of two Tainoceras monilifer specimens from the Shumway limestone (both X 1).

are less than 50 mm in width. The developing concave zones and the flattening of the sides causes the point of greatest width to move ventrally. Where the dorsolateral spine is fully developed the shell is widest at the umbilical shoulder. The dorsal impressed zone becomes apparent where the conch is 40 mm wide but is never very pronounced. The living chamber which was at least half a volution in length maintains the same general shape as the phragmocone except for the developing apertural spine. The umbilical carinae are present where the conch is 25 mm wide. Where the conch is 40 mm wide the carinae are about 2 mm high and the adoral portion of the shell is slightly flared. The height of the umbilical carinae and the degree of dorsolateral modification gradually increases as the size of the conch increases. A paratype has a portion of one apertural spine preserved. The spine is 30 mm long and 7 mm wide at its broken distal end. It is normal to the plane of coiling and essentially straight. The posterior surface of the spine is uniformly rounded. The anterior surface is not present and probably had not developed yet. Growth lines are poorly preserved ventrally on all specimens. Laterally they form a slight lateral salient.

Ventrally the camerae are deep with 3-4 occurring in the space equal to the width of the whorl. They are only moderately convex apicad. The sutures are very nearly transverse to the longitudinal axis of the conch having only a broad shallow ventral lobe and very slight ventrolateral saddles. Laterally the sutures are straight. Since the siphuncle was in contact with the venter for only part of its length, the ventral septal necks appear to converge apicad when seen on internal molds. The dorsal portion of the septal necks are cyrtochoanitic. Although the segments of the siphuncle do not appear to be in contact with the test ventrally, they are expanded within the camerae. The length of the ventral septal necks and the width of the siphuncle increases as the size of the conch increases. The siphuncle is 1.5 mm wide and the septal necks are 3 mm long where the conch is 40 mm wide and 4 mm and 6 mm respectively where the conch is 70 mm wide.

Comparison, S. shumwayense is most similar to S. brammeri Miller, Dunbar and Condra. S. shumwayense expands at a more rapid rate than S. brammeri. The ventral septal necks of S. brammeri extend half way through the camerae while those of S. shumwayense extend only 1/3 the length of the camerae. The siphuncle of S. brammeri was in contact with the test for a longer distance as the septal necks do not converge as they do in S. shumwayense. The septal necks of S. shumwayense are in direct contact with the test only near the cameral wall. They then dip down into the camerae. S. greenense is also similar but it has a distinctive siphuncle and much more pronounced concave zones. Other species of Solenochilus are not particularly close to S. shumwayense.

Family Liroceratidae Miller and Youngquist, 1949
Genus Liroceras Teichert, 1940
Liroceras liratum (Girty)
Pl. 3, fig. 4.

1911. Coloceras liratum Girty, New York Acad. Sciences, Annals, 21, p. 144.
1911. Coloceras liratum var. obsoletum Girty, New York Acad. Sciences, Annals, 21, p. 145.
1970. Liroceras liratum Murphy (includes full synonomy), Jour. Paleontology, 44, p. 203-204, Pl. 36, fig. 9.

Material. 15 specimens of this wide spread species were collected (PE 28018-PE 28032).

Description. The involute subglobose conch is reniform in cross section. The venter and sides are evenly rounded, the umbilical shoulders are abruptly rounded, and the umbilical walls are flat. The narrow deep umbilicus is about 1/4 the diameter of the conch. An indistinct ventral sulcus is present on the living chamber of specimens larger than 25 mm in diameter. The siphuncle is not visible on any specimen. Ornamentation consists of fine growth lines and revolving lirae. The growth lines form deep rounded hyponomic sinuses bordered on each side by lateral salients and a sinus slightly ventrad of the umbilical shoulders. The revolving lirae are restricted to the umbilical walls and adjacent portions of the lateral walls. None of the specimens collected (smallest = 15 mm diameter) have the lirae reaching beyond the umbilical area. Lateral lirae are persistent to a diameter of 29 mm. The sutures are essentially transverse to the longitudinal axis of the conch. The internal suture could not be observed on any of the specimens. A very indistinct conchal furrow is present on the living chambers of large individuals.

Family Ephippioceratidae Miller and Youngquist, 1949
Genus Ephippioceras Hyatt, 1894
Ephippioceras moinellae n. sp.
Pl. 3, figs. 5,6.

Etymology. This species is named for my mother encouraged and supported my studies of the Shumway Limestone faunas.

Material. The holotype (PE 27914) and paratypes (PE 27900, PE 27907-PE 27908, PE 27915-PE 27918) were collected.

Diagnosis. This species is a very depressed (about twice as wide as high), rapidly expanding Ephippioceras which has a narrowly rounded umbilical shoulder and a broad V-shaped ventral saddle.

Description. The holotype is an internal mold of about half a volution including part of the body chamber and eight adoral camerae of the phragmocone. The conch is a rapidly expanding involute nautilicone that apparently consisted of 2-3 volutions. In at least the outer volutions the whorl section is reniform being greatly depressed, broadly rounded ventrally and laterally, and more narrowly rounded dorsolaterally. The dorsum is not visible but it was surely impressed for part of its width. The whorls are about twice as wide as they are high. At the junction of the living chamber and the phragmocone the holotype is 27 mm wide and 15 mm high. The conch is widest at or just below the umbilical shoulders. The umbilicus is small and deep with a diameter of 1/8-1/11 that of the entire shell. The test is poorly preserved but appears to be smooth except for growth lines. The living chambers of large individuals have thickened growth lines that are set at irregular intervals. The living chamber of this species was at least 1/2-2/3 a volution in length. The holotype is near maturity since some paratypes whose phragmocones are about the same size as the holotype's have crowded adoral camerae. The camerae except for the ones bordering the living chamber in mature specimens are spaced at 6 mm intervals mid-ventrally and 3 mm mid-laterally. The sutures have a moderately wide slightly rounded V-shaped ventral saddle flanked on either side by a broad shallow ventrolateral lobe and a narrow slightly angular dorsolateral saddle centered on the umbilical shoulder. The internal suture and the position and nature of the siphuncle are not known. There is a conchal

furrow present on larger individuals.

Comparison. This species is much more depressed than its closest relative E. ferratum (Cox). Since all the Shumway specimens are depressed to about the same degree, the degree of depression cannot be easily attributed to distortion during preservation.

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Plate 1.

Fig. 1,2. Lateral and ventral views of a juvenile paratype (PE 27942) of Domatoceras wortheni. X 1.

Fig. 3. Longitudinal section of a paratype (PE 27925) of Domatoceras wortheni showing septal necks and connecting rings. X 2.

Fig. 4,5. Ventral and lateral views of the holotype (PE 27919) of Tainoceras sexlineatum. X 1.

Fig. 6. Lateral view of the holotype (PE 27920) of Metacoceras copei showing distal swellings of the ventrolateral nodes and irregular placement and obsolescence of the ventrolateral nodes adorally. X 1.

Fig. 7. Longitudinal section of a specimen (PE 27975) of Tainoceras monilifer showing septal necks. X 1.5.

Fig. 8. Ventral view of the holotype (PE 27887) of Solenochilus shumwayense. X 0.75.

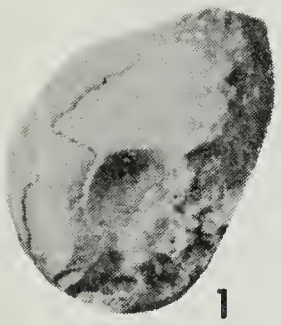

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Plate 2.

Fig. 1. Lateral view of the holotype (PE 27951) of Domatoceras wortheni. X 1.

Fig. 2. Lateral view of Metacoceras sp. (PE 27970). X 1.2.

Fig. 3. Ventral view of a paratype (PE 27886) of Solenochilus shumwayense showing developing dorsolateral spine. X 1.

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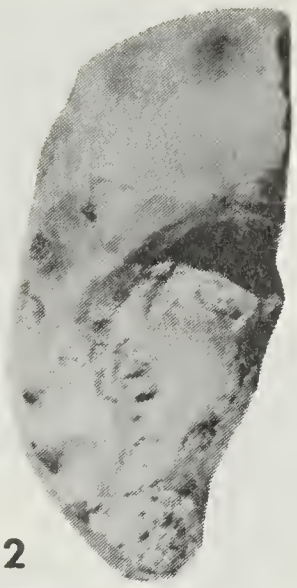

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Plate 3.

Fig. 1. Ventral view of the holotype (PE 27920) of Metacoceras copei. X 1.

Fig. 2. Lateral view of a paratype (PE 27967) of Metacoceras copei that is exfoliated and nearly complete adorally. X 1.

Fig. 3. Ventral view of a paratype (PE 27889) of Solenochilus shumwayense. X 1.

Fig. 4. Ventral view of a specimen (PE 28020) of Liroceras liratum showing slight midventral sulcus that develops at maturity. X 1.

Fig. 5. Ventral view of the holotype (PE 27914) of Ephippioceras moinellae. X 1.

Fig. 6. Lateral view of a paratype (PE 27915) of Ephippioceras moinellae. X 1.

Fig. 7. Lateral view of the holotype (PE 27960) of Domatoceras mattoonense. Note anterior and posterior borders of the periphract. X 1.1.

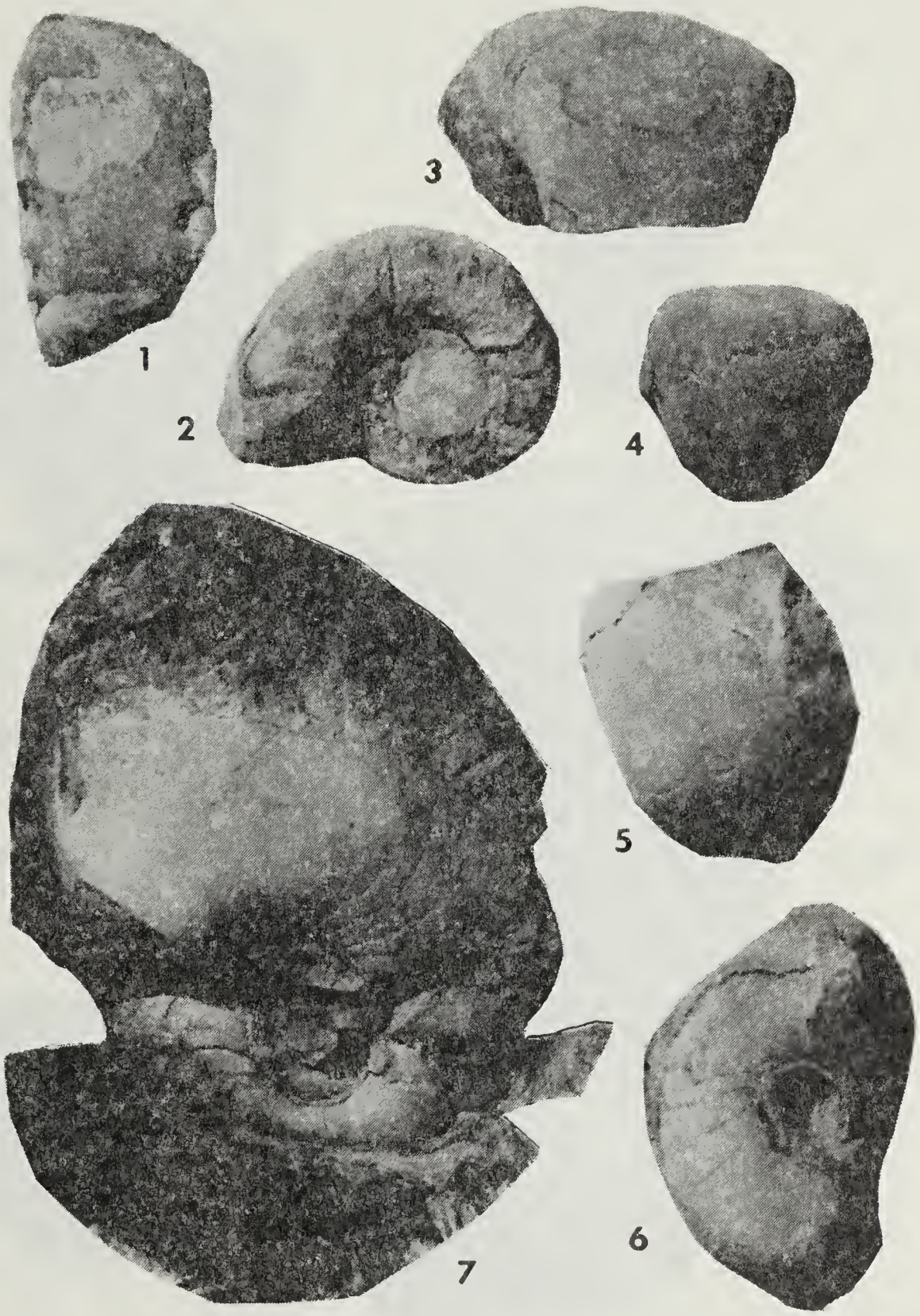
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Plate 4.

Fig. 1. Ventral view of the holotype (PE 27951) of Domatoceras wortheni. X 1.

Fig. 2. Ventral view of Metacoceras sp. (PE 27970). X 1.

Fig. 3. Ventral view of a paratype (PE 27961) of Metacoceras copei showing distal swellings of the ventrolateral nodes. X 1.

Fig. 4. Lateral view of the holotype (PE 27956) of Stearoceras involutum. X 0.9.

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METAL-METAL AND METAL-LIGAND VIBRATIONS OF SOME TIN-COBALT COMPOUNDS

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ABSTRACT--Two series of compounds containing, respectively, tetracarbonylcobalt and triphenylphosphinetricarbonylcobalt derivatives of tin with general formulas $X_{4-n}Sn[Co(CO)_4]_n$ and $X_{4-n}Sn[Co(CO)_3PPh_3]_n$ (where X = Cl, Br, or I and n = 1, 2, or 3) were prepared and their low-frequency infrared spectra studied. Assignments were made for tin-cobalt, cobalt-phosphorus, and tin-halogen stretching frequencies.

INTRODUCTION

Organometallic compounds containing covalent metal-metal bonds are of great interest. Recently, the infrared spectra of some organometallic compounds containing the triphenylphosphinetricarbonylcobalt derivatives of tin have been reported and the carbonyl stretching frequencies assigned (Hall, 1974). However, in order to identify the vibrations associated primarily with metal-metal and metal-ligand stretchings, it is necessary to look into the low-

frequency region of the infrared spectra, which also contain metal-ligand deformation modes. In the present work, two series of compounds, one series containing the tetracarbonylcobalt derivatives of tin, and the other containing the triphenylphosphinetricarbonylcobalt derivatives, were prepared and their low-frequency infrared spectra studied.

METHODS AND MATERIALS

All reactions were carried out under a static nitrogen atmosphere, and solid products were handled with minimum exposure to air. Microanalyses were performed by the Alfred Bernhardt Mikroanalytisches Laboratorium.

The low-frequency infrared spectra for the 33-800 cm^{-1} region were measured in Nujol and recorded on a Beckman IR-11 spectrometer. Calibration was made using the water line at 203.6 cm^{-1}. High density polyethylene plates were used as windows for the region below 200 cm^{-1} and cesium iodide was used for the region above 200 cm^{-1}. Spectral data are summarized in Table 1. Representative spectra are displayed in Figure 1.

Trichloro(tetracarbonylcobalt)tin(IV), $Cl_3SnCo(CO)_4$. This compound, the tribromo and the triiodo compound, $Br_3SnCo(CO)_4$ and $I_3SnCo(CO)_4$ were prepared by the method of Patmore (1968).

Dichlorobis(tetracarbonylcobalt)tin(IV), $Cl_2Sn[Co(CO)_4]_2$. This compound was prepared by the method described by Bonati (1966). The dibromo and diiodo compound, $Br_2Sn[Co(CO)_4]_2$ and $I_2Sn[Co(CO)_4]_2$, were similarly prepared.

Chlorotris(tetracarbonylcobalt)tin(IV), $ClSn[Co(CO)_4]_3$. This compound, the bromo and the iodo compound,

Table 1

Low-Frequency Infrared Spectral Data and Assignments *

COMPOUND	ν(Co-C) + δ(Co-C-O)							ν(Co-P)	ν(Sn-X)		ν(Sn-Co)
$Cl_3SnCo(CO)_4$	546s	538s,sh	486s	456s	412w	362w	360s		355s	350s	205m
$Cl_3SnCo(CO)_3PPh_3$	560s	524s	517s,sh	482m	470m			436w	345s	335s	195w
$Br_3SnCo(CO)_4$	546s	536s,sh	486m	457s	410m	365m			260s	251s	205m
$Br_3SnCo(CO)_3PPh_3$	558s	525s	520s,sh	480m	469m			434w	240s	228m	190w
$I_3SnCo(CO)_4$	543s	534s,sh	486m	456s	408w	366w			210w	200w	205w
$I_3SnCo(CO)_3PPh_3$	564m	526s	518s,sh	480m	472m			433w	226w	210w	180w
$Cl_2Sn[Co(CO)_4]_2$	540s	504m	492m	468s	408m	370w	366w,sh		336m	327m	213m
$Cl_2Sn[Co(CO)_3PPh_3]_2$	570m	558s	524s,sh	520s	499m	490m,sh	477w	435w	316w	304m	168m
$Br_2Sn[Co(CO)_4]_2$	544s	507m	487s	466s	408m	370w,sh	363w		237m	225s	209m

Table 1 (Continued)

Low-Frequency Infrared Spectral Data and Assignments *

COMPOUND	ν(Co-C) + δ(Co-C-O)							ν(Co-P)	ν(Sn-X)		ν(Sn-Co)
$Br_2Sn[Co(CO)_3PPh_3]_2$	568m	558s	524s,sh	520s	497m	491m,sh	476w	434w	221m	210m	164w
$I_2Sn[Co(CO)_4]_2$	541s	510m,sh	483s	467s	370w,sh	363w			195m	187m	202m
$I_2Sn[Co(CO)_3PPh_3]_2$	566m	556s	521s	496m	487m,sh	475w		432w	181w	172w	160w
$ClSn[Co(CO)_4]_3$	540s	505s	472s	412m	371w	367w,sh			302m		180m
$ClSn[Co(CO)_3PPh_3]_3$	578w	563s	540s,sh	521s	500m,sh	478w		433w	290w		152w
$BrSn[Co(CO)_4]_3$	546s	505s	472s	411m	373w	366w			216m		181m
$BrSn[Co(CO)_3PPh_3]_3$	576w	562s	540s,sh	521s	498m,sh	478w		434w	208w		152w
$ISn[Co(CO)_4]_3$	543s	508s	500s,sh	472m	410m	370w			177m		180m
$ISn[Co(CO)_3PPh_3]_3$	576w	562s	540s,sh	520s	503s,sh	478w		435w	167w		146w

* m - medium; s - strong; sh - shoulder; w - weak

$BrSn[Co(CO)_4]_3$ and $ISn[Co(CO)_4]_3$, were prepared by the method of Patmore (1966b).

Trichloro(triphenylphosphinetricarbonylcobalt)tin(IV), $Cl_3SnCo(CO)_3PPh_3$. This compound, the tribromo and the triiodo compound, $Br_3SnCo(CO)_3PPh_3$ and $I_3SnCo(CO)_3PPh_3$, were prepared by the method described earlier (Hall, 1974).

Dichlorobis(triphenylphosphinetricarbonylcobalt)tin(IV), $Cl_2Sn[Co(CO)_3PPh_3]_2$. This compound, the dibromo and diiodo compound, $Br_2Sn[Co(CO)_3PPh_3]_2$ and $I_2Sn[Co(CO)_3PPh_3]_2$, were prepared by insertion reaction as described by Patmore (1966a).

Chlorotris(triphenylphosphinetricarbonylcobalt)tin(IV), $ClSn[Co(CO)_3PPh_3]_3$. This compound, the bromo and the iodo compound, $BrSn[Co(CO)_3PPh_3]_3$ and $ISn[Co(CO)_3PPh_3]_3$, were prepared by the method described earlier (Hall, 1974).

RESULTS AND DISCUSSION

The spectral range investigated in this work was 33-800 cm^{-1}. No important feature other than the choppy baseline and the Nujol band at 70 cm^{-1} was observed in the 33-100 cm^{-1} region. The characteristic bands associated with triphenylphosphine as described by Edgell (1965) were present in all the $Co(CO)_3PPh_3$ derivatives in the 690-750 cm^{-1} region. Such bands were of course absent in the $Co(CO)_4$ derivatives. It is interesting to point out that the number and position of the bands for triphenylphosphine were independent of the number of $Co(CO)_3PPh_3$ groups.

The low-frequency region of infrared spectra of metal carbonyls has received very little attention. Consequently, very few assignments have been made. In the 300-600 cm^{-1}

region are found metal-carbon stretching vibrations, ν(M-C), and metal-carbonyl deformation modes, δ(M-C-O). The distinction between the δ(M-C-O) deformation and the ν(M-C) stretching vibrations is not clearcut although there can be little doubt that the higher frequency bands are essentially δ(M-C-O) and the lower frequency bands are ν(M-C) stretching vibrations (Jones, 1963; Edgell, 1963). The extent of overlapping between δ(M-C-O) and ν(M-C) and coupling of vibrations of the same symmetry types is probably extensive. Standard group theory treatment reveals a total of 5 infrared-active bands of ν(M-C) and δ(M-C-O) for mono-$Co(CO)_3PPh_3$ derivatives and 7 bands for mono-$Co(CO)_4$ while the bis- and tris-derivatives of $Co(CO)_3PPh_3$ and $Co(CO)_4$ possess 14 or more infrared-active bands. Only in the mono-$Co(CO)_3PPh_3$ derivatives were the predicted number of infrared-active ν(M-C) and δ(M-C-O) bands observed. The bis- and tris-derivatives of both $Co(CO)_4$ and $Co(CO)_3PPh_3$ revealed only 6 or 7 bands.

From the work of Westland (1965), and Rivest (1967), metal-phosphorus stretching frequency appears to lie in the range of 430-480 cm^{-1}. In all the $Co(CO)_3PPh_3$ derivatives of tin, the band that appeared in the range of 432-436 cm^{-1} was assigned the ν(Co-P) stretching. This band was of course absent in the $Co(CO)_4$ derivatives. It is interesting to note that the position and intensity of the ν(Co-P) stretching was not affected by the halo-group on tin nor by the number of $Co(CO)_3PPh_3$ groups.

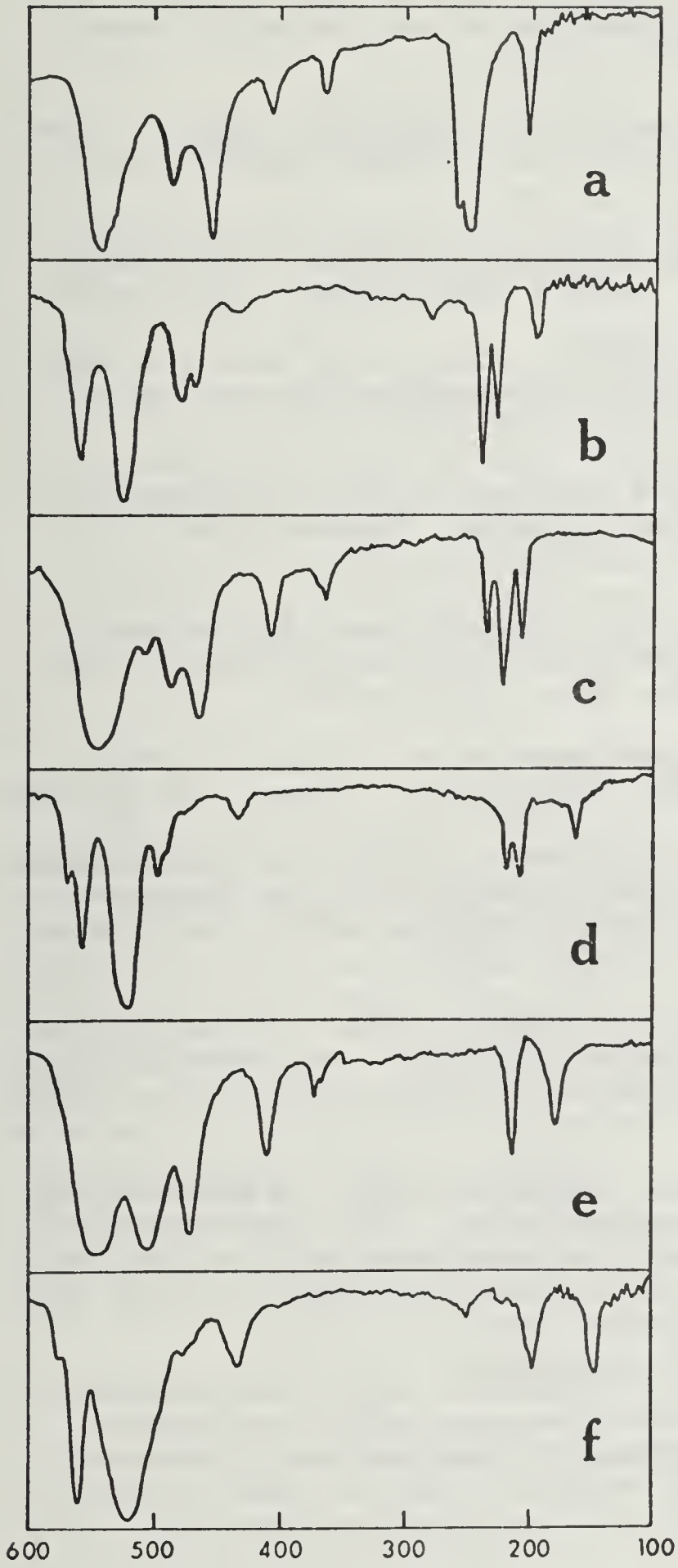
On the basis of available information on metal-halogen stretching frequencies (Brasch, 1968; Nakamoto, 1970), some useful empirical rules for assignment can be given as follows: 280-350 cm^{-1} for ν(M-Cl); 190-250 cm^{-1} for ν(M-Br); and 150-200 cm^{-1} for ν(M-I). Assignments for ν(Sn-Cl), ν(Sn-Br) and ν(Sn-I) are summarized in Table 1. Wherever two bands were observed, the higher frequency band was

assigned the asymmetric stretching while the lower frequency band, the symmetric stretching of the tin-halogen bond.

Tin-halogen deformation modes are generally very weak and occur at much lower frequencies than the stretching vibrations. The choppiness of the baseline in the spectra below 150 cm^{-1} made assignments difficult as small features must be treated with doubt. No attempt was thus made in such assignments.

Owing to the synthetic effort at present being expended on heteronuclear metal-metal bonded systems, there is increasing interest in stretching frequencies associated with such bonds. Clark (1965) examined the compound $(CH_3)_3SnCo(CO)_4$, and assigned the band at 176 cm^{-1} the ν(Sn-Co) stretching frequency. In the present work, the band in the 180-210 cm^{-1} region for the $Co(CO)_4$ derivatives is assigned the ν(Sn-Co) stretching and the band in the 150-195 cm^{-1} region for the $Co(CO)_3PPh_3$ derivatives is assigned the ν(Sn-Co) stretching. When the terminal carbonyl group is replaced by a triphenylphosphine group, the tin-cobalt stretching frequency is at a lower frequency. The higher ν(Sn-Co) stretching frequencies in the $Co(CO)_4$ derivatives are probably due to configuration interaction or coupling of vibrational modes of the same symmetry type. While the ν(Sn-Co) stretching frequencies do not seem to depend on the type of halogen present, it does depend on the number present. The ν(Sn-Co) vibrations shift to lower frequency as the number of halogen decreases.

Figure 1. Low-Frequency Infrared Spectra of Some Tin-Cobalt Compounds.



(a) $Br_3SnCo(CO)_4$

(b) $Br_3SnCo(CO)_3PPh_3$

(c) $Br_2Sn[Co(CO)_4]_2$

(d) $Br_2Sn[Co(CO)_3PPh_3]_2$

(e) $BrSn[Co(CO)_4]_3$

(f) $BrSn[Co(CO)_3PPh_3]_3$

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VARIATION IN THE CAUDAL SKELETON OF *ETHEOSTOMA NIGRUM* RAFINESQUE (OSTEICHTHYS:PERCIDAE).

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ABSTRACT

23 *Etheostoma nigrum nigrum* Rafinesque, 34 intergrades and 17 *E. n. eulepis* (Hubbs and Greene) were cleared and stained. *E. nigrum* has the Type F caudal fin. Three patterns of fusion of the hypural bones were found. No significant difference was found between the frequency of fusion between subspecies. Number of branched caudal rays varied greatly within each subspecies. Because of its variation, caudal structure does not seem taxonomically useful at this level.

INTRODUCTION

Schlueter and Thomerson (1971) reported on the variation of the caudal skeleton of *Etheostoma caeruleum* Storer, but failed to mention if the caudal fins varied between local populations or as a result of hybridization with other species. This paper examines the variation in caudal fins of the Central Johnny Darter, *Etheostoma nigrum nigrum* Rafinesque and, the Scaly Johnny Darter, *E. n. eulepis* (Hubbs and Greene). Underhill (1963) suggests that the subspecies rank of *E. n. eulepis* be discarded. Collette and Knapp (1966,p.18) agreed with Underhill, stating the elevation to subspecies rank does not aid in understanding the complex distributional pattern. Hubbs (1961,p.15) cites *E. n. eulepis* and *E. n. nigrum* as an apparent dramatic illustration of the force that resists swamping, as well as the power of the ecological potential. My investigation was sparked by the possibility of finding new evidence for understanding this complex problem.

MATERIALS AND METHODS

Specimens were preserved in 10% formalin, later washed in running tap water and transferred to 40% isopropanol. Darters were identified to subspecific level (Hubbs and Lagler, 1964). If any of the three areas of the nape, cheeks and breast of a fish were sparsely squamated (area covered by scales less than 50%) or naked, then the fish was assigned to the intergrade group.

All 74 specimens were collected in Northern Illinois in 1973. De Kalb Co.: Indian Creek, bridge on Chicago Rd.: Sept. 7, (4 *E. n.*

nigrum:5/1 five intergrades one of which had fused hypurals:0 E. n. eulepis). Sept. 11, (7:19/2:4). De Kalb Co.: Somanauk Creek, 180 m south of bridge on Pratt Rd.: Sept. 7, (0:1:1). De Kalb Co.: Owens Creek, bridge on Hwy. 72: Sept. 19, (1:3/1:2/1). De Kalb Co.: Coon Creek, bridge on Hwy. 72: Sept. 19, (4/2:2:3). Oct. 5, (7/1:1:6/3). Jo Daviess Co.: Apple River, bridge on Farm Rd., 0.1 mi. south of Hanover on Hwy. 84: Sept. 29, (0:3/1:1).

Instead of severing the fish at the caudal peduncle, as did Schlueter and Thomerson (1971), the entire fish was cleared and stained, using a technique modified from Taylor (1967), Davis and Gore (1936), and Hollister (1934). Numbering of the hypurals follows Lundberg and Baskin (1969).

RESULTS

Of the 74 specimens examined, 62 showed no hypural fusion (83.8%), 3 of the 23 E. n. nigrum showed hypural fusion (13.0%), 5 of the 34 intergrades had fused hypurals (14.7%), 4 of the 17 E. n. eulepis had fused hypurals (23.5%). The G statistic (Zar, 1974) for the log-likelihood ratio goodness of fit test was calculated for the frequencies of fusion of the hypurals according to subspecies as G=0.83873, degrees of freedom=2, $0.50 < P < 0.75$. The null hypothesis, H_o: The frequency of fusion of hypural plates as independent of subspecies., was accepted.

Etheostoma nigrum has the Type F caudal fin of Lundberg and Baskin (1969,p.15). Three patterns of fusion of the hypural bones were found: fused hypurals 1-2 (6 fish), 3-4 (5) and P-1-2 (1) (see Figure 1).

Branched caudal rays for subspecies and intergrades all had a mode of 14. Specimens of E. n. nigrum had: branched rays 13 (4 fish), 14 (15), 15 (4). Intergrade specimens had: 12 (1), 13 (4), 14 (23), 15 (4), 16 (1), 17 (1). Specimens of E. n. eulepis had: 12 (1), 13 (2), 14 (8), 15 (3), 16 (3).

DISCUSSION

Only three types of hypural fusion were found for E. nigrum as compared to the 9 types found for E. caeruleum by Schlueter and Thomerson (1971). The greater variation found for E. caeruleum is based on a larger sample size (491 specimens). Radiographs of the caudal fins of this species would be of only limited value. Often it is impossible to tell from a cleared and stained specimen if fusion has occurred until manipulating the hypurals with forceps. The higher frequency of fusion of the hypural plates of the eulepis form was found to be insignificant for my sample. Since there is no significant difference of fusion between subspecies, and because each specimen is essentially destroyed by the clearing and staining process, hypural fusion as a character for separation of subspecies seems nonproductive.

The number of branched caudal rays was highly variable with no discernible differences between subspecies.

CONCLUSIONS

No significant difference in fusion of hypural plates was found for subspecies of E. nigrum. E. nigrum has the Type F caudal fin. Branched caudal rays vary greatly within each subspecies.

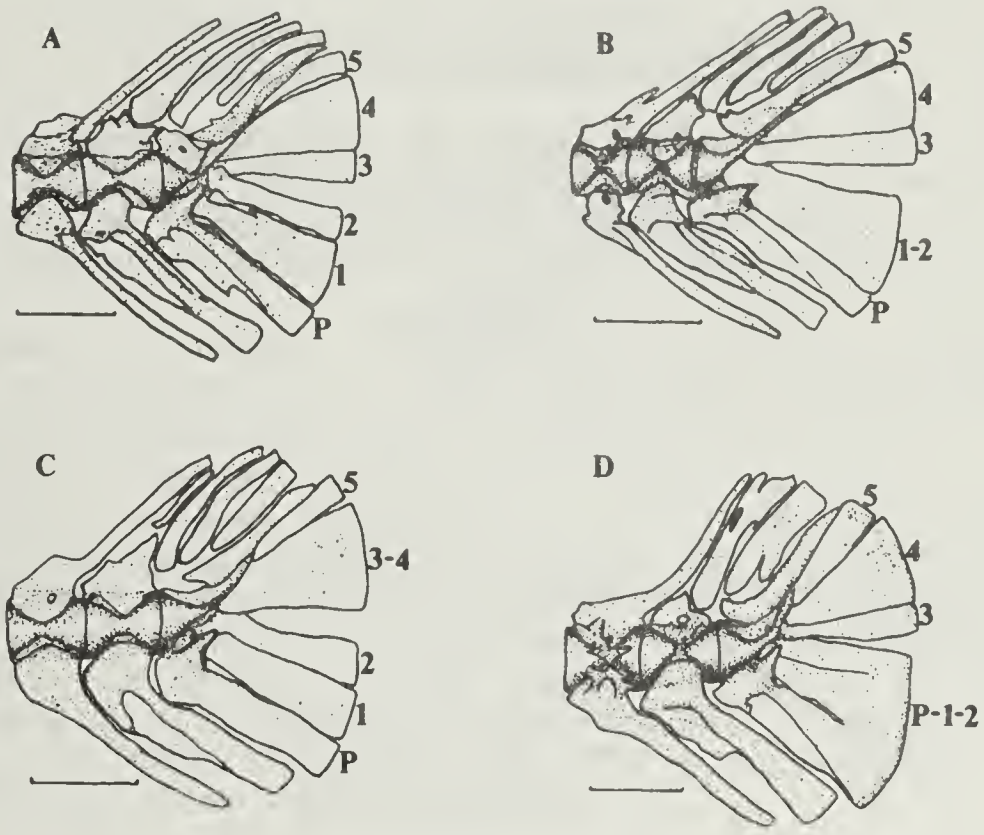

Fig. 1. Caudal skeletons of Etheostoma nigrum: A. Normal configuration of 41.38 mm E. n. eulepis, P=parhypural, 1-5=hypurals, scale 1.0 mm; B. Fused hypurals (1-2) of 36.71 mm intergrade; C. Fused hypurals (3-4) of 43.23 mm E. n. eulepis; D. Fused parhypural and hypurals (P-1-2) of 49.13 mm intergrade.

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REPRODUCTION IN MESOVELIA MULSANTI (HEMIPTERA: MESOVELIIDAE)

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ABSTRACT

The duration of the preovipositional period is correlated with temperature and the three thoracic morphs. At 25.6° C, this period averages 3.6 days for wingless, 3.4 days for intermediate and 6.5 days for winged females. The significant difference between the averages for flightless (wingless and intermediate) and winged females results in two age-specific fecundity schedules. A decline in hatchability and viability occurs among progeny from aging females.

INTRODUCTION

Mesovelia mulsanti White occurs as three thoracic morphs: wingless, intermediate (flightless adults that develop from nymphs with wing pads) and winged (Galbreath, 1975). Young winged adults have whole hemelytra and wings; in older individuals, the apices of hemelytra and wings are broken and the indirect flight muscles undergo autolysis. At Lawrence, Kansas, and Carbondale, Illinois, oviposition is continuous in successive, overlapping generations from May until late October or early November. Eggs overwinter (Galbreath, 1973).

The egg was described by Hungerford (1917), who figured eggs embedded in the stem of sedge. Eggs may also be laid on surfaces (Hoffmann, 1932). Hungerford pointed out that a matrix must be provided for the females to insert their eggs; he and Hoffmann used plants. Neering (1954) and Galbreath (1969) placed two layers of moistened brown paper toweling in the bottom of rearing containers to simplify egg counts which were done by turning over the top layer of paper. The toweling also provided humidity and its brown color contrasted with the white color of a newly laid egg. Cobben (1968) utilized polystyrene foam and grass stems.

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This paper presents data on the duration of the preovipositional period for the three thoracic morphs under differing temperatures. Age-specific fecundity data are given for intermediate and winged females.

MATERIALS AND METHODS

Reproductive data were accumulated in studies on thoracic polymorphism and diapause (Galbreath, 1969, 1975, 1976 and unpublished data). All experiments in Table 1 started with the collection of fourth and fifth instars in the field. The method of distinguishing the morphs and the rearing technique were given in Galbreath (1975). All nymphs were reared in isolation, except in expt. 6. When the adults emerged, single-pair crosses were established. In expt. 3, there were 15 crosses or more of each of the nine possible crosses (three morphs, sexes taken reciprocally). In expt. 2 records were kept on the age of each female when it died; a few females were terminated early when they only laid eggs on surfaces because these eggs never developed embryos.

Differing conditions of temperature and photoperiod were used (Table 1). In expt. 6 the nymphs (five per container) and, after emergence, the adults (single-pair crosses) were maintained under eight photoperiods. During the dark period in expt. 6 and 8, M. mulsanti were kept in cardboard boxes.

Daily counts of the eggs, inserted and laid on surfaces, were made using a stereoscopic microscope (60X). The toweling containing eggs from one female for one day of oviposition was separated to place five or six eggs in a container--a precaution to reduce future cannibalism. For expt. 2 and expt. 4 (Galbreath, 1975), records were kept relating the age of the female parent and the survival of its progeny to the first and fourth instars (This species does not deviate from the norm of five instars. Fourth instars of the wingless morph were preserved to facilitate the handling of more progeny.). The fourth instars included some dead late third instars where the morph was recognized in dissections.

RESULTS

Eggs. Eggs are usually inserted through the upper layer of toweling, but may be embedded within the first layer of toweling or inserted into the second layer of toweling. The laying of eggs on surfaces was noted. The adults may feed upon any of the eggs. Neither Hoffmann (1932) nor I observed that any of the eggs laid on surfaces hatched. Correlation of the age of females and the hatchability of eggs showed that the laying of eggs on surfaces could be related to infertility in young females and senility in old females.

Duration of immature stages. The following data were obtained from nondiapause progeny reared from two females collected as nymphs from the same pond in 1960 at Carbondale, Illinois (Galbreath, 1969). The first rearing took place

from Jul. 8 to 30 and the second rearing from Sep. 30 to Nov. 16. At fluctuating temperatures averaging 30.0° C, range 27.7° to 33.3°, incubation requires an average of 6.5 days (range 6-7) and the nymphal stage, 12.0 days. At fluctuating temperatures averaging 23.9° C, range 21.1° to 27.2°, incubation lasts 11.7 days (range 11-12) and the nymphal stage, 20.5 days (range 20-22). Other data are available on incubation (Galbreath, 1973) and nymphal stadia (Galbreath, 1975). The European M. furcata Mulsant and Rey has an incubation of about 20 to 24 days and a total nymphal period of about 45 days (Jordan, 1931); this may be due to cooler temperatures.

A morph-related difference in the duration of nymphal development in M. mulsanti was not observed as reported in Gerris by Poisson (1924), Larsén (1950) and Guthrie (1959), but was discounted by Brinkhurst (1963), Andersen (1973) and Vepsäläinen (1973).

Preovipositional period. Table 1 and Figures 1A and B, Lines B, record the duration of preoviposition. At 25.6° C, this period averaged 3.5 days for wingless and intermediate females, data pooled, and 6.5 days for winged females. These averages are significantly different ($t=4.8$; $P=<.0005$). Neither the eight differing photoperiods of expt. 6 nor the decreasing natural daylengths of expt. 8 had any influence on preoviposition. Likewise, the morph of the male in expt. 3 did not change the duration of this period. It appears that the maturation of the testes occurs at the same age in flightless and winged males. More data on preoviposition are found in Hungerford (1917) and Hoffmann (1932).

Duration of generation. The duration of generation for nondiapause individuals was determined from the already mentioned expts. of 1960 and from expts. 2 and 4 of Table 1. One generation from adult to adult averaged: 24.0 days for two progeny from a winged female at 30.0° C, 26.1 days (range 20-33) among 17 progeny from winged and intermediate females at 26.7° C, 33.0 days (range 26-37) among seven progeny from winged and wingless females at 25.6° C and 41.0 days (range 39-44) among four progeny from an intermediate female at 23.9° C. The data at higher temperatures agree with the cycle of 24 days reported by Hungerford (1917).

Age-specific fecundity data. Table 2 and Figures 1A and B, Lines D, give two age-specific fecundity schedules. Unpublished studies by me have shown that the age-specific fecundity data for wingless females do not differ from those given here for intermediate females. The maximum in egg production and the age when it occurs are important to the innate capacity for increase (Birch et al., 1963). As shown in Table 2, maxima reached in egg production were 645 for intermediate females seven days old and 449 for winged females nine days old.

Survival. Figures 1A and B, Lines A, record the survival of adult females during preoviposition. In this example 52 intermediate females (1 died) and 46 winged females (1 flew away, 7 died) survived preoviposition. The survival is sig-

Table 1. Duration in days of preoviposition in Mesovelia mulsanti at differing temperatures in the laboratory.

Morph: Wingless[1]	Morph: Intermediate	Morph: Winged	Mean temp in °C[2]	Number of experiment, dates of preoviposition, city, state[3]
3.2[4] (2-6)[5] 55[6]	4.0 (3-5) 2	7.1 (5-12) 8	27.9	1, Jul. 25-Aug. 11, 1957, Lawrence, Kans.
-	2.8 (1-5) 52	6.0 (3-10) 46	26.7	2, Jun. 24-Jul. 21, 1961, Carbondale, Ill.[7]
2.8[8] (1-6) 53	3.2[8] (2-4) 47	8.1[8] (3-16) 52	26.2	3, Jul. 25-Aug. 28, 1970, Carbondale, Ill.
3.6 (2-6) 45	3.4 (2-5) 11	6.5 (4-11) 36	25.6	4, Sep. 1-14, 1961, Carbondale, Ill.
4.9 (3-7) 19	5.2 (4-7) 4	12.7 (7-19) 18	23.9	5, May 28-Aug. 15, 1957, Lawrence, Kans.
5.6[9] (3-13) 160	5.0 - 1	12.5 (9-18) 4	22.8	6, Sep. 30-Oct. 21, 1973, Carbondale, Ill.
7.5 (7-8) 4	7.0 (5-8) 9	17.0 (6-28) 32	21.4	7, Sep. 20-Oct. 27, 1970, Carbondale, Ill.
7.7 (6-12) 9	6.0 - 1	18.0 (13-21) 6	20.4	8, Oct. 6-28, 1972, Carbondale, Ill.
-	-	37.0 (27-46) 2	20.0	9, May 15-Jul. 9, 1959, Carbondale, Ill.

1/ Wingless individuals were identified as fourth instars in expts. 3, 4 and 7. The remaining females lacked wing pads as fifth instars (Galbreath, 1975, Fig. 2H) and could not be distinguished with certainty from the rarest intermediate (Fig. 2G).

2/ Fluctuating temperatures: expt. 1, mean 27.9° C, range 25.5°-35.0°; expt. 2, mean 26.7° C, range 21.1°-32.2°; expt. 3, mean 26.2° C, range 20.0°-30.0°; expt. 4, mean 25.6° C, range 19.4°-31.1°; expt. 6, mean 22.8° C, range 18.3°-27.2°; expt. 7, mean 21.4° C, range 17.8°-28.2°; expt. 8, mean

Table 1. Continued.

20.4° C, range 17.2°-23.3°. Air conditioned temperatures: expt. 5, mean 23.9° C, range 18.8-27.2°. Controlled temperature chamber: expt. 9, set at 20.0° C, range 18.3°-20.0°.

3/ Light. Expts. 1-4, 7, natural light plus artificial during work at night. Expt. 5, artificial light during research. Expt. 6, photoperiods of light: dark, 16:8, 15:9, 14:10, 13:11, 12:12, 11:13, 10:14 and 9:15. Expt. 8, decreasing natural daylengths, i.e., 11.6 hrs. on Oct. 6 to 10.6 hrs. on Oct. 28. Expt. 9, no data.

4/ Average number of days.

5/ Range in days.

6/ Number of females.

7/ Further details of this experiment are given in Table 2 and Figures 1A and B.

8/ Data pooled from three samples.

9/ Data pooled from eight samples.

Table 2. Age-specific fecundity data for intermediate and winged females of Mesovelia mulsanti at 26.7° C.

Age in days after last molt	Daily egg production: intermediate N of females	N laying eggs	N of eggs	Rate of oviposition[1]	winged N of females	N laying eggs	N of eggs	Rate of oviposition
1	53	0	0	0	54	0	0	0
2	53	2	14	7	53	0	0	0
3	52	24	146	6	51	0	0	0
4	51	40	432	11	51	2	10	5
5	50	47	560	12	50	6	27	4
6	45	45	594	13	48	17	149	9
7	42	42	645	15	45	31	280	9
8	40	40	544	14	45	38	413	11
9	33	33	503	15	43	42	449	11
10	27	27	303	11	39	38	446	12
11	20	20	222	11	34	34	402	12
12	13	13	112	9	33	33	379	12
Total		333	4075			241	2555	
Average[2]			77				47	
Rate of oviposition				12				11

1/ Eggs per female per day to the nearest whole number.

2/ Average number of eggs per female 12 days old to the nearest whole number.

nificantly influenced by temperature. Pooled data (expts. 2 and 4) for wingless and intermediate morphs show that 92.3% (N=117) survived this period. Similar data for 1974 under

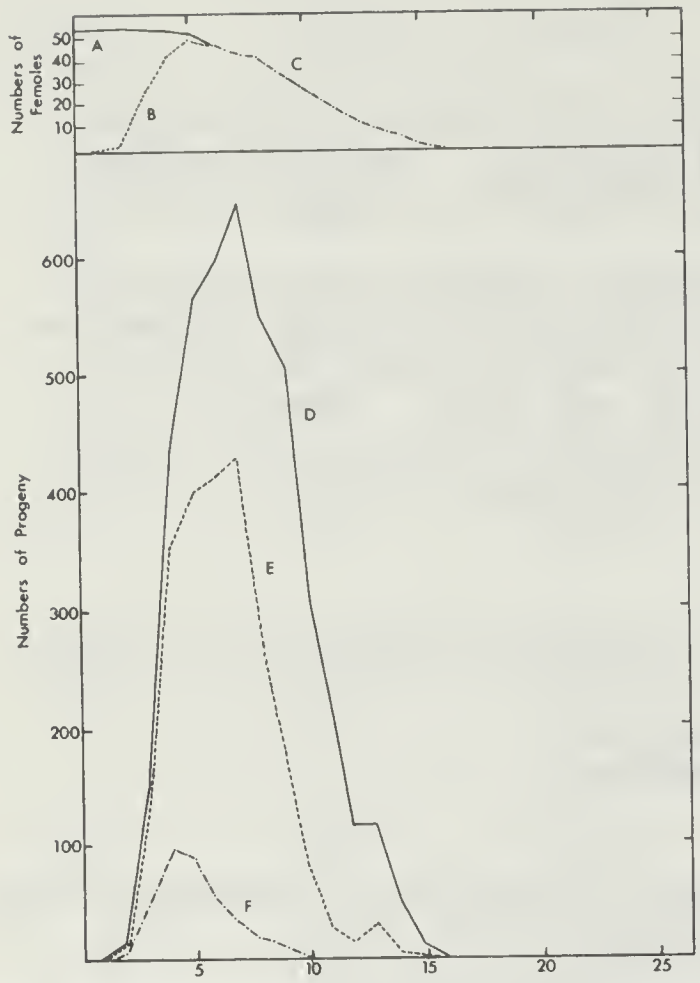

Fig.1A. Age of Mothers in Doys after Lost Molt

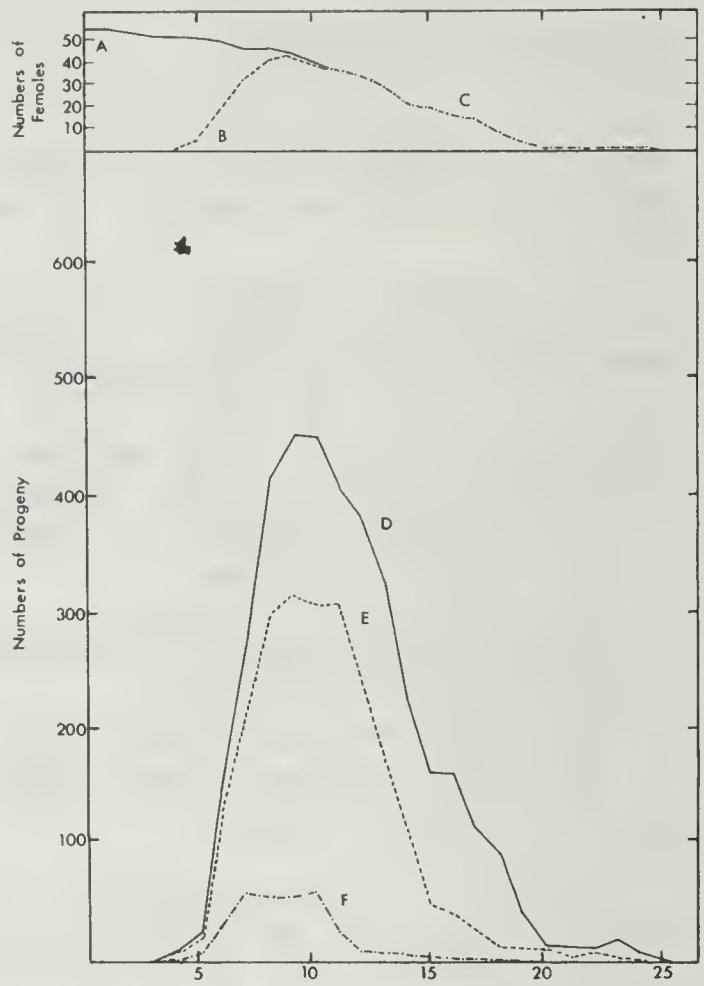

Fig. 1B. Age of Mothers in Days after Last Molt

Fig. 1. Age-specific data of Mesovelia mulsanti at 26.7° C. Figure 1A applies to intermediate females and Figure 1B applies to winged females: the number of females surviving (Lines A), the number of females ovipositing during the early period of reproduction (Lines B), the number of surviving females that were inserting their eggs into matrix (Lines C), the number of eggs laid daily (Lines D), the number of first instars (Lines E) and the number of fourth instars (Lines F) surviving from eggs laid on any one day.

outdoor temperatures of late summer and early autumn gave a survival of 73.1% (N=156; chi-square=40.0; P=<.005). Pooled data from 1955 through 1974 on winged females show that at 25° C or higher 88.6% (N=167) survived and at lower temperatures 67.8% (N=99; chi-square=90.0; P=<.005).

In expt. 6, the survival during preoviposition was 60.5% (N=267) for flightless females. I do not know if this low percentage could be attributed in part to crowding as the adults emerged in rearing containers with five individuals.

Table 2 and Figures 1A and B, Lines C, give data on survival of the adults during the ovipositional period. Beginning at the age of six days, more winged females survived than did intermediate females. In M. mulsanti, the duration of oviposition is not a meaningful statistic because of the decline in the survival of progeny with in-

creasing age of the females (see next paragraph). Therefore I have used the duration of time during which females laid eggs which hatched into nymphs that could be reared to the fourth instar. There is no correlation between the average duration of this period and the morph of the female parent: expt. 2, 3.2 days (range 1-7) for intermediate females, 4.0 days (range 1-10) for winged females; expt. 4, 3.4 days (range 1-7) for wingless and intermediate females, 4.0 days (range 1-7) for winged females. Two records at lower temperatures, 7 days for an intermediate female at 23.9° C and 4 days for a winged female at 20.0° C, are insufficient to state if temperature could influence the duration of this period. Data on the duration of oviposition are recorded (Galbreath, 1976).

Figures 1A and B demonstrate the decline in hatchability (Lines E) and viability (Lines F) both of which were related to the age of female parents in expt. 2. In this experiment the survival from egg to fourth instar was 9% (N=8,284) because progeny were reared throughout the period of oviposition; whereas in expt. 4, the survival was 15% (N=4,484) due to the fact that progeny were reared only from the first seven days of oviposition.

DISCUSSION

M. mulsanti is the only known gerroid with a morph-related difference in the preoviposition of nondiapause females. Other Gerroidea overwinter as adults in a reproductive state of diapause (Vepsäläinen, 1971b; Andersen, 1973). Consequently, a difference occurs in the duration of preoviposition between diapause females and those that do not overwinter. In Gerris odontogaster (Zetterstedt) in southern Finland, nondiapause adults are short-winged and diapause adults are winged; photoperiod is the control for the difference in preoviposition (Vepsäläinen, 1971b). In G. lacustris (Linnaeus) in Denmark, nondiapause adults are predominately short-winged with few winged individuals but diapause adults are short-winged or winged; the control of the duration of preoviposition is not fully understood (Vepsäläinen, 1971a, 1974a; Andersen, 1973; Darnhofer-Demar, 1973). I would say that the preovipositional data of Hydrometra martini Kirkaldy (Sprague, 1956) also shows a difference between nondiapause and diapause females.

The morph-related difference in preoviposition in M. mulsanti is important in studying thoracic polymorphism. The occurrence of the morphs as nymphs is correlated with temperature (Galbreath, 1975). Nymphs of the more common wingless morph are collected when the estimated mean air temperatures range from a spring low of 16.7° C to a summer high of 28.3° C to a fall low of 8.3° C. Nymphs of the rarer intermediate and winged morphs are found primarily when the estimated mean air temperatures are 21.5° C or higher. The present study shows that wingless females have the advantage of a shorter preovipositional period throughout the

seasonal activity. Likewise intermediate females have a shorter preoviposition. While winged females have a longer preoviposition, its duration is mitigated by high temperature thus keeping the reproductive disadvantage of winged females to a minimum.

Two reports of a morph-related difference in fecundity between short-winged and winged females of the Gerroidea (Poisson, 1924; Sprague, 1956) have not been substantiated with gerrids (Brinkhurst, 1959; Guthrie, 1959; Andersen, 1973; Vepsäläinen, 1974b). Study of Andersen's method and data suggests to me that further work could show significant morph-related differences in age-specific fecundity.

Young wingless and intermediate females of M. mulsanti lay more eggs than do young winged females because of a shorter preovipositional period. In my opinion this supports an idea expressed by Andrewartha and Birch (1960: 240) that "an increment in the innate capacity for increase can be most readily obtained by enhancing the rate of egg production early in the female's life." Differences in the duration of preoviposition in young M. mulsanti apparently came about in its evolutionary history through the development of flightless morphs.

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ILLINOIS FARMSTEADS: ISLANDS FOR BIRDS?

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ABSTRACT

Sixteen central Illinois farmsteads, mostly smaller than 1.5 ha, were censused to test whether birds colonize farmsteads as islands of habitat in otherwise hostile cropland. Compared to one farmstead in a wooded area, the small, isolated farmsteads seemed similar to each other, with few significant trends relating habitat and bird populations. Resident bird species correlated poorly with total farmstead area, but more highly with large deciduous trees and with an index of total deciduous tree area. The effect of farmstead area and tree area was greater on resident bird species than on residents plus transient species. The number of woodland species was unrelated to farmstead habitat parameters. Bird abundances were variable on farmsteads, but followed a log-series distribution. The farmsteads were dominated by several abundant, generalist species, and woodland species seemed unable to populate these farmsteads. Farmsteads poorly fit the habitat island concept for birds, and cannot be expected to preserve many woodland species in central Illinois.

INTRODUCTION

During the past half century, major trends in Illinois agriculture have been the removal of hedgerows and trees, reduction of farm animals, and an increase of corn and soybean acreage (Graber and Graber, 1963). In central and east Illinois, acreage devoted to row crops rose 42% from 1945 to 1974, while small grains and hay fell 75% (Moats, 1968; Kendall, 1975). Much of central and east Illinois are now denuded, except for trees along creeks and on scattered farmsteads. Graber and Graber (1963) documented numerous changes in Illinois bird populations due to these trends.

Recent studies on fragmentation of woods suggest that woodlot size affects the type and number of bird species found there (Forman et al., 1974; Moore and Hooper, 1975; Whitcomb et al. in press). MacArthur and Wilson (1967) developed a substantial theory relating the number of species on oceanic islands to island size and isolation. Culver (1970),

Vuilleumier (1970), and Brown (1971) applied the island concept to terrestrial habitats, and the above authors applied it for woodlots. The extension of island theory to habitats was not always successful, however. The fragmented nature of farmsteads in central Illinois led me to ask whether birds colonize these as islands. Do birds respond to area of farmsteads? Are most Illinois farmsteads below some threshhold, such as territory size of birds, and hence unusable by most birds? Are area of land, area of trees and shrubs, or variety of habitat types on a farmstead most important? Farmsteads in this study provided an opportunity to examine the above questions, and to evaluate the man-made effects of farmstead isolation on birds.

STUDY AREA AND METHODS

In this study a farmstead includes a set of farm buildings and the associated farmyard with grass, trees, and cowlots. Most farmsteads were surrounded by plowed fields during the study. One farmstead was surrounded by woods, considered part of the farmstead, and three had pastures (not included in the censuses) connected to them. Sixteen farmsteads were selected along the township roads outlining the E ½ of Section 30 and all of Sections 25-29 of T26N, R2W of the Third Principal Meridian, Tazewell and Woodford Counties, Illinois. Fifty farmsteads were along 25 km of roads in this area. A woods in excess of 80 ha was near the southeast corner of the study area. Another woods over 40 ha was within 400 m of the northeast corner, but off the area. One farmstead sampled included the woods at the southeast, but 14 farmsteads were over 1.6 km from a woods, and several were approximately 5 km from any woods. The precise farmstead locations in this study are available upon request.

All birds seen and heard on each farmstead were recorded for three minutes between 0629 and 1146, on each of May 16, May 17, and June 1, 1975. This sample time is that of the Breeding Bird Survey (Robbins and Van Velzen, 1969). The area of the farmsteads, the number and relative size of deciduous and evergreen trees and shrubs, the number and relative size of buildings, and the presence of livestock were recorded.

Variables are defined as follows: AREA is farmstead area in ha (correlations were computed using thousands of square feet); LGT is large trees over 14 m tall; SHRB is number of shrubs; LGE is number of large evergreens over 7 m tall; LBLD is number of major buildings over 70 m^2; CATGY is the number of habitat categories present on the farmstead (13 possible, consisting of shrubs, 4 sizes of deciduous trees and evergreens each, 2 building sizes, and 2 livestock types); HAB is a habitat diversity index, computed as LGT/3 + medium trees (over 9 m) /10 + small trees (over 3 m)/25 + SHRB/5 + LGE/5 + medium evergreens (over 4.5 m)/15 + 1 if cows or hogs were present + LBLD/5 + small buildings/10, where all values are truncated to whole numbers in computation; TREE is an estimate of deciduous tree area, computed as LGT + medium trees x 0.37 + small trees x 0.049 + tiny trees (1 m or less) x 0.0044 + SHRB x 0.0123; EVERG is an estimate of coniferous tree area, computed as LGE + medium evergreens x 0.3 + small evergreens (over 2 m) x 0.072 + tiny evergreens (about 0.6 m) x 0.012. NOSPT is the total species of

birds recorded on a farmstead; NOSPM is the mean species number recorded per census period on a farmstead; NOSP3 is the number of species recorded all 3 days on a farmstead; NOSPW is the number of species recorded on a farmstead, where nonforest species are excluded; ABUND is the mean bird abundance per farmstead. TREE and EVERG are designed to approximate the cross-section area of the trees. HAB is computed from natural history observations of farmsteads such that a value of 1 might represent a significant habitat to birds if isolated in a plowed field. For example, 3 large trees, 5 shrubs, or 10 small buildings in the center of a plowed field might harbor a bird species not otherwise found there, whereas one shrub or small building would probably not attract a new species to a plowed field.

RESULTS AND DISCUSSION

Pearson product-moment correlations were computed between habitat variables and the bird variables. Stepwise multiple regressions were performed, using bird variables as dependent variables. These analyses were performed on the data from the 16 farmsteads to test overall trends from small farmstead to farmstead in woods. Because the one farmstead in woods was more than an order of magnitude larger than any other, and had 18 species, whereas no other farmstead exceeded 10 species, I performed a second analysis with the wooded farmstead removed. This second analysis combined three pairs of farmsteads which were adjacent, using combined habitat descriptions and reduced 3-minute samples for each pair. The second analysis tested for trends found among smaller, isolated farmsteads (n=12).

The data for the 16 farmsteads, including NOSPT, ABUND, LGT, SHRB, TREE, LGE, LBLD, AREA, and HAB, are included in appendix. The species observed are listed, together with the number of farmstead occurrences. Table 1 presents the significant Pearson product-moment correlations between habitat and bird variables.

For the total number of species observed on the farmsteads, NOSPT, I computed the slope z of the species-area relation:

$$\log S = z \log A + \log C$$

where S is the number of species on a farmstead, A is the area of the farmstead, and C is a constant (MacArthur and Wilson, 1967). For NOSPT on the isolated farmsteads without woods, the species-area slope z was 0.00 $\pm$0.03 (95% confidence limit; r=0), and the species-tree area slope z was 0.09 $\pm$0.02 (r=+). When the wooded farmstead was included, the species-tree area slope z was .18 $\pm$0.02 (r=0.71). For the mean number of species seen per farmstead per census, NOSPM, the species-area slope (isolated farmsteads only) was 0.11 $\pm$0.05 (r= +), and the species-tree area slope was 0.17 $\pm$0.02 (r=0.73). For the resident number of species on farmsteads, NOSP3, the species-area slope (isolated farmsteads only) was 0.25 $\pm$0.13 (r= +), and the species-tree area slope was 0.34 $\pm$0.19 (r= +).

Of the 10 correlation sets listed in Table 1, the number of large trees and tree area exceeded farmstead area 10 times. Habitat diversity exceeded area 9 times. These differences are significant (Chi-square sign test), and AREA seems less important than LGT, TREE, or HAB. SHRB, LGE, and EVERG were significantly less correlated with bird variables

TABLE 1. Product-moment correlations between habitat and bird variables. The upper values are for the 16 farmsteads, including one with woods. The lower values are for 12 farmsteads (3 pairs are grouped; woods is omitted). Significant correlations are given, and correlations of absolute value less than .20 are indicated by 0. Variables are defined in text.

VARIABLE	AREA	LGT	SHRB	LGE	LBLD	CATGY	HAB	TREE	EVERG
With wooded farmstead									
NOSPT	.88	.89	.62	.76	.57	0	.90	.90	.76
NOSPM	.77	.84	.51	.63	.54	0	.80	.82	.61
NOSP3	+	+	0	+	+	.49	+	+	0
NOSPW	.92	.92	.71	.81	.52	-	.94	.93	.81
ABUND	0	+	0	0	+	.60	+	+	+
Without wooded farmstead									
NOSPT	0	+	0	0	0	-	+	+	0
NOSPM	+	.66	0	0	+	+	+	.62	0
NOSP3	+	.59	0	0	+	.75	.62	.59	0
NOSPW	0	0	0	0	0	-	+	+	0
ABUND	0	+	-	0	0	+	0	+	0

than AREA was (sign test).

The multiple regression on NOSPT (isolated farmsteads only) was
NOSPT = 6.67 +0.12 (TREE) -0.03 (AREA) +0.48 (LBLD) R = 0.80
where all habitat parameters significantly contribute to the equation. The effects of TREE and AREA are codominant here, based on partial correlation. The multiple regression on NOSPM confirmed the dominance of TREE, and neither AREA nor other habitat variables added any additional significance. For resident birds on isolated farmsteads,
NOSP3 = 0.62 (CATGY) +0.13 (HAB) - 2.22 R = 0.86
where both parameters significantly contribute to the regression. For woodland birds on isolated farmsteads,
NOSPW = 2.48 -0.01 (AREA) +0.19 (medium evergreens) +0.14 (LGT) R =0.90
where all 3 parameters contribute significantly to the multiple regression. These equations confirm that habitat variety and vegetation are at least as, and often more, important than farmstead area alone in affecting bird species. MacArthur and Wilson (1967) suggested that the role of increased area in increasing the number of species was probably due to increased habitat diversity, but they gave no evidence for this.

On these 16 farmsteads, the species abundances were not significantly different from a log-series distribution ($P > .10$), as expected by May (1975). Six species were found on 11 or more farmsteads, and comprised 91.5% of all birds seen. Twenty-three other species were rarer. The house sparrow (Passer domesticus), starling (Sturnus vulgaris), and common grackle (Quiscalus quiscula) accounted for 79% of all birds seen. Of all Illinois habitats censused by Graber and Graber (1963), this bird community is most similar to urban residential areas, with high dominance

of a few species. House sparrows, starlings, common grackles, and American robins (Turdus migratorius) comprised 84% of the birds observed in this study, and these 4 species comprise 82 to 89% of 3 Chicago north side and suburban, poorly wooded, residential areas (Guth, unpublished). These same generalist, flocking species appear both in city and farm as abundant, dominant birds. A highly significant correlation existed between the number of farmstead occurrences and the mean abundance per occurrence ($r = 0.75$; $n = 29$ species).

Because the generalist species on farmsteads reached high and variable abundances, the correlations between habitat parameters and bird abundance were not significant, except for CATGY, the number of habitat types on a farmstead (Table 1). The significant correlations with CATGY of number of resident species and bird abundance suggest that with more habitat types, more birds can survive on a farmstead. Total abundance of woodland species showed no significant trends with habitat parameters on isolated farmsteads. The abundance of woodland birds was significantly correlated with the number of woodland species ($r = 0.75$), but for all species on the farmsteads, the correlation between abundance and number of species was 0.

DISCUSSION

Some species were seen on all three censuses, but others were seen only one or two times on a farmstead. The total species seen in the 3 days may be interpreted as the resident species plus transients. Resident species might be at equilibrium with their environment, with local immigrations and extinctions, and should follow the island model. Transients frequently use all farm area (farmsteads and cropland) more uniformly. Numerous small migrants stop in city residential areas, business districts, city parks, fencerows, or farmsteads (Guth, unpublished). In this study common grackles, barn swallows (Hirundo rustica), starlings, and other species flew out to feed in the land between farmsteads, and therefore I expect a low species-area slope for transients.

Total bird species (residents and transients) did have flat species-area and species-tree area slopes. The steeper slopes of resident species, NOSP3, approach values to be expected for islands, whereas the slopes of 0.00 or 0.09 are often expected in non-island situations (MacArthur and Wilson, 1967). The confidence intervals on the resident slopes were large, and the correlations were not significant for these species-area relations, perhaps due to small sample sizes. Because the total number of species, including transients, had a flat species-area slope, and the resident species did not show significant species-area slopes for these isolated farmsteads, there is little evidence for an island interpretation.

The decline in significant correlations (Table 1) when the wooded farmstead is removed provides additional evidence that isolated farmsteads are not colonized as islands by birds. The lack of significant correlations with NOSPW, the number of woodland species, confirms the unsuitability of these isolated farmsteads for birds. Total abundance of woodland species correlated significantly with AREA ($r = 0.82$) and TREE ($r =$

0.83), but also showed no significant trends on isolated, unwooded farmsteads. The unwooded farmsteads of this study, ranging in size from 0.27 ha to 2.94 ha (mean = 0.92), are too small or too denuded to attract many bird species other than edge species. Moore and Hooper (1975) computed z = 0.271 in their study of British woods, and showed that many species do not occupy very small woods, but will consistently occupy larger woods, indicating a threshhold effect. The flat species-area and species-tree area slopes further indicate that these farmsteads are below some threshhold.

Of the 29 species observed in this study, 18 were found on the one farmstead surrounded by woods, and 20 were found on the remaining 15 isolated, smaller farmsteads. Simberloff and Abele (1976) suggest that an archipelago of small islands will usually contain more species than a single large island of similar area. In this farmstead set, 15 farmsteads with a mean of 7.7 species out of possibly 29 species should have 28.7 species. These 15 farmsteads have only 20 species because not all species are equally likely to inhabit a farmstead as the Simberloff-Abele model assumes. This difference between the abundant, generalist farmstead birds, and forest birds which are rare on farmsteads, or found only in larger wooded areas, suggests a potential conservation problem. Generalist birds on farmsteads respond more to vegetation than to area, for farmsteads are structurally different from woodland. Farmsteads are not adequate habitat islands for most birds, and much larger wooded areas are needed to preserve birds on Illinois farms than the farmsteads alone.

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APPENDIX. Bird and habitat parameters for 16 Illinois farmsteads.

Farmstead Number	NOSPT	ABUND	LGT	SHRB	TREE	LGE	LBLD	AREA	HAB
1	7	30.0	4	8	8.7	7	3	.91	6
2	18	24.0	100	40	199.0	35	8	48.56	89
3	6	26.7	3	3	6.4	0	4	.60	2
4	9	15.7	3	10	17.9	1	1	.58	7
5	6	12.7	0	27	1.3	1	2	.58	5
6	9	7.7	7	2	10.0	0	5	.51	3
7	9	13.7	4	17	5.3	1	4	.79	4
8	9	23.7	0	4	10.2	0	6	.82	5
9	8	17.0	0	20	2.1	17	2	.27	7
10	10	26.7	22	9	26.9	0	3	.37	10
11	7	14.7	3	9	5.7	0	3	.53	3
12	7	11.0	3	3	5.3	0	2	.50	1
13	9	33.0	9	3	12.0	0	6	1.26	5
14	6	13.7	5	7	6.3	1	1	.36	2
15	6	18.0	14	9	20.2	0	5	1.26	7
16	7	18.0	8	7	19.6	8	6	1.68	9

Species observed on 16 Illinois farmsteads, with number of farmsteads of occurrence: Passer domesticus,16; Quiscalus quiscula,16; Sturnus vulgaris,14; Hirundo rustica,13; Turdus migratorius,13; Melospiza melodia,11; Vermivora peregrina,7; Agelaius phoeniceus,6; Passerina cyanea,6; Chaetura pelagica,4; Molothrus ater,4; Columba livia,2; Zenaida macroura,2; Troglodytes aedon,2; Spinus tristis,2; Mimus polyglottos,2; Centurus carolinus,1; Myiarchus crinitus,1; Cyanocitta cristata,1; Corvus brachyrhynchos,1; Parus bicolor,1; Sitta carolinensis,1; Dumetella carolinensis,1; Toxostoma rufum,1; Hylocichla mustelina,1; Sturnella magna,1; Icterus galbula,1; Cardinalis cardinalis,1; Spizella passerina,1.

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BLOOD CHEMISTRY IN FROGS AND TURTLES

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ABSTRACT

Blood of frogs and turtles was analyzed quantitatively by clinical instrumentation for chemicals known to be of clinical importance in higher species including man. The determination of such values, particularly for enzymes, is of interest from the standpoint of evolution, biomedical research and laboratory animal science.

INTRODUCTION

Although some blood chemistry values are available for common ectothermic laboratory animals, such as frogs and turtles, the values exist in scattered sources. The knowledge concerning the presence and quantitation of those enzymes known to be of importance in the detection of cellular damage in mammalian disease is especially fragmentary in the ectotherms. Such knowledge has been documented for several mammalian animals (Burns and de Lannoy Jr., 1966; Burns, Timmons and Poiley, 1971; Melby and Altman, 1974; Schalm, Jain and Carroll, 1975) and for man (Bioscience Laboratories Handbook, 1973).

The present data collate and expand the knowledge of blood chemistry in frogs and turtles with special reference to enzyme values.

MATERIALS AND METHODS

The frogs were the northern variety of Rana pipiens (males and females), all about 60 gm. They were fed crickets, then fasted for three days, at 22° C. All frogs used presented a healthy appearance, without muscle flaccidity, postural hypotonia, cutaneous hemorrhage, pigmentation loss, or noticeable abdominal or limb edema. On necropsy evidence of internal parasites was absent or slight.

The turtles used, Pseudemys scripta elegans (males and females), were healthy adults, 5-6 inch shell length. They were fed canned liver dog food wetted with cod-liver-oil, then fasted for three days.

Frogs were rendered unconscious by pithing. After exposing the thorax, blood was drawn from the cardiac ventricle through a 20 gauge needle. For

hemoglobin and the hematocrit, heparinized whole blood was used. For creatine phosphokinase (CPK), heparinized whole blood was centrifuged and the plasma was used. For all other chemicals tested, serum was used.

To obtain serum, untreated whole blood was allowed to clot for 15 minutes. The tube containing clot and supernatant fluid was centrifuged at 4,000 RPM for 5 minutes. If the supernatant serum was colored pink, which denotes red cell hemolysis, the sample was discarded, because hemolysis can interfere with the quantitative determination of enzyme concentrations.

The serum was immediately withdrawn by pipet and microliter samples were utilized in determinations of lactic dehydrogenase (LDH), glutamic oxaloacetic transaminase (GOT), glutamic pyruvic transaminase (GPT), alkaline phosphatase, uric acid, blood urea nitrogen (B.U.N.), cholesterol, glucose, total protein, and albumin. Determinations were completed within four hours of drawing the blood.

Similar procedures were used for turtle blood. A 1 cm hole was bored in the plastron with an electric drill, and blood was obtained by cardiac puncture using an 18-gauge needle. Euthanasia was by overdose of sodium pentobarbital.

Blood analyses, except for the packed cell volume and the enzyme CPK, were performed with an Accu-Stat System (Clay-Adams Automated Laboratory Equipment, Division of Becton-Dickinson and Co., Parsippany, N.J. 07054). This instrument gives data within a limit of accuracy acceptable for clinical purposes, while permitting the use of very small samples. CPK determinations were obtained by a Sigma procedure (Sigma Chemical Co., St. Louis, MO 63178) involving a Spectronic 70 in which ATP interacts with creatine to produce ADP and phosphocreatine, the reaction being catalyzed by CPK. The phosphocreatine is then hydrolyzed to creatine and inorganic phosphorus. The phosphorus is measured colorimetrically at 520 nm and is proportional to CPK activity. The PCV was determined in a microhematocrit centrifuge (Hematocrit Model No. 34, Chicago Surgical and Electrical Co., Melrose Park, IL 60160).

Sex differences and differences between frog and turtle blood were analyzed by the Student t test for independent means, the level of significance selected at $p = 0.01$.

RESULTS

Data for healthy fasted frogs and turtles are listed in Table 1 along with comparison literature values for the cat and man.

There are no significant sex differences between frogs and turtles for any of the chemicals studied, although such differences exist as tendencies, e.g. PCV is higher in the males of both frogs and turtles.

There are species differences. Alkaline phosphatase is significantly higher in turtles than in frogs, but both values lie approximately within the range of the cat and man.

TABLE 1.

Blood Chemistry baseline values in frog (Rana pipiens) and turtle (Pseudamys scripta elegans)

Chamical constituent	Units used	Maan, standerd deviation and ranga		Cat	Man
		Frog	Turtle		
Alkaline phosphatase	Babson (I.U./L)	24.4 ± 9.1 (6-43) (17 males, 5 females)	42.8 ± 16.2 (10-75) (15 males, 10 females)	8-46 I.U./L	9-35 I.U./L
Glutamic Pyruvic transaminase (GPT)	I.U./L	25.0 ± 6.5 (12-38) (25 males, 4 females)	21.9 ± 10.3 (5-42) (15 males, 10 females)	1-67 I.U./L	10-35 I.U./L
Glutamic oxaloacetic transaminase (GOT)	Karmen/ml	490.2 ± 168.4 (110-785) (16 males, 6 females)	219.8 ± 48.4 (123-317) (15 males, 10 females)	2-43 I.U./L	8-40 Karmen/ml =4-20 I.U./L
Lactic dehydrogenase (LDH)	Wacker/ml	114.7 ± 23.3 (68-161) (12 males, 11 females)	106.2 ± 29.1 (48-164) (15 males, 10 females)	42-420 Wacker/ml	8-20 Wacker/ml =40-60 I.U./L
Creatine phosphokinase (CPK)	Sigma/ml	71.9 ± 25.8 (20-124) (17 males, 14 females)	39.8 ± 18.3 (3-76) (16 males, 10 females)	0.5-1.5 Sigma/ml	0-12 Sigma/ml =0-100 mIU/ml
Packad cell volume (PCV)	ml/100 ml whole blood	35.4 ± 8.15 (25-57) (12 males, 15 females)	28.4 ± 5.4 (18-39) (13 males, 10 females)	37 ml/100 ml	40-50 (male) 37-47 (female)
Hamoglobin	gm/100 ml whole blood	7.1 ± 1.0 (5-9) (16 males, 6 females)	9.2 ± 2.9 (3-15) (13 males, 10 females)	7.9-15.5 gm/100 ml	13-18 (male) 11-16 (female)
Glucose	mg/100 ml	30.8 ± 6.9 (17-45) (15 males, 7 females)	96.0 ± 18.2 (56-132) (15 males, 10 females)	39-130 mg/100 ml	70-110
Cholesterol	mg/100 ml	83.9 ± 43.4 (35-180) (16 males, 6 females)	140.8 ± 45.6 (80-260) (15 males, 10 females)	60-136 mg/100 ml	150-250
Total Protein	gm/100 ml	3.3 ± 0.5 (2-4) (16 males, 6 females)	4.7 ± 0.5 (4-6) (14 males, 9 females)	6.6-8.9 gm/100 ml	6.0-8.2
Albumin	gm/100 ml	1.2 ± 0.2 (1-2) (16 males, 6 females)	1.8 ± 0.9 (0.5-4) (14 males, 9 females)	3.5-4.6 gm/100 ml	3.5-5.5
Blood urea nitrogen (B.U.N.)	mg/100 ml	11.9 ± 4.6 (3-21) (16 males, 6 females)	21.6 ± 8.4 (5-38) (14 males, 9 females)	14-31 mg/100 ml	5-25
Uric acid	mg/100 ml	4.0 ± 2.4 (1-9) (15 males, 6 females)	1.6 ± 0.5 (1-3) (17 males, 15 females)	0.3-3.2 mg/100 ml	2.0-7.8

Frogs (avg. weight 60 gm) and turtles (shell length 5-6 inches), held prior to use at room temperature, were used. Serum was enalyzad except where otherwise notad in the Table. The normal values for the enzymes were determined at 37 C. Turtle blood is significantly differant from that of frogs ($p<0.01$) in alkaline phosphatase, GOT, CPK, total protain, albumin, hemoglobin, cholesterol, glucose, blood urea nitrogen, uric acid, and packed cell volume. There ara no sex differances at $p=0.01$.

GPT and LDH are in the same range for the frog, turtle, cat and man. Differences between frogs and turtles are not significant for either enzyme.

GOT and CPK are highest in the frog and significantly reduced to about half those values in turtles. GOT and CPK are far lower in the cat and man, the two latter species being in the same range.

The PCV is significantly higher in frogs than in turtles, but both these values lie approximately within the lower range of the cat and man.

Hemoglobin is significantly higher in turtles than in frogs. Both values are below the cat and human mean values.

Glucose is significantly higher in turtles than in frogs. Turtle blood glucose lies in the range of the cat and man.

Cholesterol is significantly higher in turtles than in frogs. The turtle is in the high range of the cat and in the low range of man.

The total protein and serum albumin are significantly different between frogs and turtles. They are low in frogs, higher in turtles, and still higher in the cat and man (the latter two being in the same range).

Blood urea nitrogen is significantly higher in turtles than in frogs. The turtle B.U.N. value lies within the range of the cat and man.

Uric acid is significantly higher in frogs than in turtles. The turtle uric acid value lies within the range of the cat and man, and the frog value lies only within the range of man.

DISCUSSION

Baseline values for biochemical blood constituents in common laboratory ectothermal species are necessary in a conveniently collated form.

Because some anticoagulants used in plasma collection interfere with enzyme activity, serum was chosen for determining enzyme concentrations except for CPK.

The effects of anesthesia or pithing on serum enzyme concentration in ectotherms are unknown. Literature values should be listed with known specifications. Our frog data are for pithed specimens.

Our enzyme studies deal with rates, which are temperature dependent. The analyses on drawn blood were performed with blood samples warmed in the machine to 37° C which duplicates conditions in the mammalian system. It allows literature comparison with mammals. For ectotherms *per se*, data obtained at the lower laboratory room temperature at which they were held might more accurately specify the living conditions for enzyme operation, although it might increase the time necessary for the test and it would change the end-point where the values are read.

In accepting the validity of blood chemistry and hematologic values listed for ectotherms, strict attention may have to be paid to seasonal biorhythms. Kaplan (1954) found that in the breeding season of frogs there is a significant decrease in hemoglobin, a tendency for the number of red blood cells to fall, and a loss of plasma, these changes affecting both sexes similarly. Kaplan (1960) also reported on seasonal blood changes in pseudemyd turtles. The present studies are limited to summer and fall.

The enzymes discussed herein have been found in the lowest vertebrates (Eckroat, 1975; Markert et al., 1975). From an evolutionary standpoint, the presence of such enzymes from fish to man indicates that it was not necessary to "invent" new cell enzymes for similar vital processes despite the diversity of the species.

For serum enzyme concentrations (which are ultimately intracellular in origin), frog and turtle blood are usually in the same range as man and some of the enzymes of these ectotherms exceed human values. Intracellular activity in ectotherms is not as sluggish as might be supposed.

One possible application of enzyme analysis in ectotherms may lie in the use of enzymes as tools to diagnose cardiac, liver or bone disorder, as is done in mammals. Also, ectotherms may be an adjunctive resource to mammals for enzyme studies in general.

SUMMARY

Quantitative analysis of important blood chemicals, especially selected enzymes, in frogs and turtles, is reported within a range of accuracy useful (1) in laboratory animal medicine and (2) as baseline values in comparative animal physiology.

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SOLANUM PLATANIFOLIUM SIMS: STUDIES ON THE PETROLEUM ETHER EXTRACT OF THE BERRIES

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Abstract.--The petroleum ether extract of Solanum platanifolium Sims seed-free berries was investigated by chromatographic and spectroscopic techniques. The C_{20}-C_{35} n-alkanes, C_{25}-C_{28} n-alkanols, and a mixture of known sterols were identified. An undetermined triterpenoid was also isolated.

Until the initial report (Bhatnagar and Puri, 1974) on Solanum platanifolium Sims from the State of Himachal Pradesh, India, no prior investigations with this particular species were known. Their first chemical studies utilized the berries in which a considerable amount of solasodine, a potential steroidal hormone precursor, was noted. Later work (Puri and Bhatnagar, 1975) revealed the presence of solasonine and a glucose-galactose-rhamnose glycoside of solasodine termed solatifoline in the alcohol extract of the leaves. Solamargine as well as these latter two alkaloids was located in the seeds and fruits.

Subsequent work with this species concentrated upon the petroleum extract of the seeds (Puri and Bhatnagar, 1976) and the seed-free berries which comprise the subject of this paper. In the seed oil the presence of saturated and unsaturated fatty acids, such as palmitic, steric, oleic, and linoleic acids, was demonstrated. The unsaponifiable portion of the seed oil consisted of n-alkanols and sterols. The n-alkanol mixture had C_{26}(19.1%), C_{27}(7.8%), C_{28}(60.7%), and C_{30}(6.5%) as the major components. The sterol mixture analyzed as sitosterol (63.9%), stigmasterol (24.1%), campesterol (9.6%), and cholesterol (2.4%).

From the petroleum ether soluble fraction of other Solanum species several alkanes, alkanols, and sterols have been indicated. For instance, Ardenne et al. (1965) reported that S. polyadenum leaves contained the C_{18}-C_{30} n-alkanes with nonacosane (C_{29}) as the principal one, while the leaves of S. demissum had the alcohols, hexacosanol and octacosanol. In another paper these authors (1965a) disclosed triacontane (C_{30}) was the main alkane (51%) in S. tuberosum leaves. Rodriguez-Miguens and Ribas-Margues (1972) found the C_{21}-C_{27} odd numbered n-alkanes and the C_{26}-C_{30} even numbered n-alkanols present in 1.5% in S. tuberosum cork. Hentriacontane (C_{31}) was the main alkane in the leaves of S. chacoense

(Uzarwicz and Mierzwa, 1971).

The leaves of S. tuberosum were also reported (Ardenne et al., 1965a) to contain β-sitosterol (49%), stigmasterol (36%), cholesterol (12%), and campesterol (3%). The occurrence of cholesterol in higher plants, in fact, was first demonstrated with S. tuberosum by Johnson et al. (1963). Others containing β-sitosterol are S. bulbocastanum (Johnson and Sato, 1969), S. cyananthum (Rizk and Abou-Zied, 1970), S. elaeagnifolium (Appel and Wildgruber, 1969), S. giganteum (Govindachari et al., 1969), and S. indicum (Varshney and Khan, 1971). Banerjee et al. (1974) isolated sterolin or sitosterol glucoside from the berries of S. aethiopium. The sterol carpesterol was derived from S. ferox (Gupta and Garg, 1968).

Sterol mixtures have been discovered in a number of other varieties. β-Sitosterol as well as brassicasterol and the galactoside of cholesterol were located in leaves of S. dulcamara (Köstens and Willuhn, 1973). A wider variety of sterols which included cycloartanol, cycloartenol, β-sitosterol, stigmasterol, campesterol, and cholesterol was reported for S. demissum and S. polyadenum (Ardenne et al., 1965) and for S. xanthocarpum (Küsano et al., 1973).

This study of the petroleum ether fraction of S. platanifolium berries was initiated to determine how the seed-free berries differed chemotaxonomically from its seeds as well as other members of the genus and to ascertain if any new compounds were present.

METHODS AND RESULTS

General. Dry powdered, seed-free berries (1.5 kg) of Solanum platanifolium Sims were exhaustively extracted (20 hr) with petroleum ether (bp 60-80°). Removal of the solvent in vacuo yielded 19 g of residue which was subjected to column chromatography on alumina. The column was eluted with solvents of increasing polarity, i.e., pet. ether, pet. ether-benzene, benzene, benzene-chloroform, and chloroform; and 70 fractions of 150 ml each were collected. Those fractions which exhibited single identical spots upon thin layer chromatography (TLC) were combined and treated as indicated below. Fractions which contained little material or were mixtures of the various single spots were set aside.

n-Alkanes. The petroleum ether fractions (1-16) gave 1.75 g of material which was recrystallized from acetone to mp 62-65°; ν_{max} (KBr) 2945, 2910, 1460, 1375, 720, and 710 cm^{-1}. Gas liquid chromatography (GLC) analysis of the material was carried out on a Varian 2700 instrument with a flame ionization detector (f.i.d.) and Autolab System IV integrator using a 1.5 m x 3.5 mm column of 1.5% OV-101 on 100/120 HP Chromosorb G at a nitrogen flow rate of 60 ml/min. The chromatograph was programmed from 90-240° at 4°/min. The main n-alkanes were found to be C_{21}(10.5%), C_{26}(1.6), C_{27}(5.5), C_{28}(3.8), C_{29}(36.3), C_{30}(7.1), C_{31}(41.1), and C_{33}(1.6) while C_{20}, C_{22}, C_{25}, and C_{32} were present in less than 1.0%.

n-Alkanols.--Elution with 3:1 petroleum ether: Benzene (Frs. 26-32) resulted in 2.7 g of material with mp 76-78°; ν_{max} (KBr) 3400, 2950, 2850, 1465, 1070, 725, and 715 cm^{-1}. GLC of the material under the above con-

ditions but at a fixed column temperature of 250° indicated it to be composed of the C_{25}(1.1%), C_{26}(27.9), C_{27}(5.7), and C_{28}(65.3) straight chain alcohols.

Unknown. Later fractions (36-49) eluted with petroleum ether-benzene (1:3) yielded 2.78 g of a substance, mp 230-235°, which exhibited a pink color in the Liebermann-Burchard test. It had λ_{max} (EtOH) 237 nm; $[\alpha]_D$ +65° ($CHCl_3$); ν_{max}(KBr) 3509, 1729, and 1250 cm^{-1} and gave a positive hydroxamate test (Meigh, 1955) for an ester moiety. An acetate, mp 163°, could be formed with acetic anhydride-pyridine.

Hydrolysis of the unknown substance with ethanolic potassium hydroxide under nitrogen produced only an oil after acidification of the reaction mixture and extraction with ether. An infrared spectrum of the hydrolyzed material was devoid of the 1729 and 1250 cm^{-1} peaks.

Sterols. Use of benzene:chloroform (1:3) as the eluting solvent gave 0.35 g of material (Frs. 56-59) with a mp of 140°. A positive Liebermann-Burchard test for sterols was observed. TLC of this fraction on silica gel G with n-heptane-benzene-ethanol (50:50:2) according to the procedure of Farnsworth et al. (1968) indicated only one spot.

A digitonide derivative could be prepared by adding a 0.5% solution of digitonin in ethanol (2 ml) to the sterol (5 mg) in ethanol (5 ml). The mixture was then warmed on the steam bath to dissolve any remaining solids. Upon cooling a precipitate, mp 240°, was formed.

GLC analysis of the sterols was performed with an F & M 3370A Model 402 instrument (f.i.d) and Hewlett-Packard integrator using a 2.55 m by 6 mm glass column packed with 5% OV-101 on Anakrom ABS 80/90. The column temperature was maintained at 275°, and a helium flow rate of 120 ml/min was employed. The sterol fraction was shown to consist of sitosterol (51.3%), stigmasterol (41.4%), campesterol (6.1%), and cholesterol (1.2%),

DISCUSSION

Several interesting comparisons can be made with the data obtained from the petroleum ether extract of Solanum platanifolium seed-free berries and prior results with its seeds as well as other members of this genus. For example, in the alkane fraction it can be noted that no single n-alkane dominates the mixture but that two-nonacosane (C_{29}) and hentriacontane (C_{31}) - in almost similar amounts comprise the main part (75%) of the mixture. These results can be considered in fair agreement with that of others since either of these two n-alkanes have been reported as the main alkanes in several species. The notable exception, however, is the record (Ardenne et al., 1965a) of triacontane as the major alkane (~51%) in S. tuberosum leaves. This finding is even more unusual since triacontane is an even-numbered alkane not normally found in such abundance.

When the composition of the n-alkanols from the berries is correlated with that of its seeds, it can be noted that both contain octacosanol (>60%) as the main straight chain alcohol with hexacosanol as the secondary one. However, the distribution is such that these two alkanols

amount to 93% of this fraction in the berries while they are only 80% of the total in the seeds. Also, triacontanol is present in 6.5% of the seed n-alkanols while it is absent in the berries.

Analysis of the sterol fraction from the berries of S. platanifolium indicates that β-sitosterol is the main component (51%) although stigmasterol is present in sufficient quantity to make the β-sitosterol-stigmasterol ratio 1.2:1. The corresponding ratio in the sterol fraction of the seeds was 2.6:1 caused primarily by a lower amount of stigmasterol.

Preliminary results with the unknown fraction obtained from the column chromatography indicate it to be homogeneous. It has been tentatively classed as a triterpenoid ester on the basis of Liebermann-Burchard and hydroxamate tests. Spectral data shows the presence of hydroxyl and ester moieties, but further information is lacking.

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A CASE OF MELANISM IN *THAMNOPHIS RADIX*

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Abstract.--A melanistic plains garter snake, *Thamnophis radix*, is reported from northern Illinois.

Melanism in the snake genus *Thamnophis* has apparently only been reported for *T. sirtalis*, *T. elegans vagrans*, and *T. ordinoides* (see Wright and Wright 1957). Although Smith (1961) mentioned a melanistic trend for *T. radix* from northeastern Illinois, and a "slightly melanistic" central Illinois *T. radix* has been cited (Morris 1975), heavily melanistic plains garter snakes have not been recorded. This note documents the occurrence of the phenomenon in *T. r. radix*.

An extremely dark *T. r. radix* (INHS 9763) was collected 7 October 1965 at Winthrop Harbor, Lake County, Illinois by Philip W. Smith. This snake exhibits a suffusion of dark pigment to a far greater degree than any other *T. radix* examined. Stripes are present on the specimen, but they are obscure, and even before preservation were dull (typically *T. radix* displays a brilliant yellow or orange dorsal stripe). The lateral stripes are gray (tan in normal *radix)*. The venter, throat, and infralabials are slaty; even the chin, while whitish and in strong contrast to the rest of the ventral aspect, is dark when compared with normal animals. The ground color appears to be solid black; however, a pattern of dark spots can be discerned if the specimen is immersed in fluid.

Normally colored garter snakes frequently become quite dark after long storage in formalin. In such examples, though, the stripes and dorsolateral spotting remain fairly evident, the venter shows some light areas (especially on the tail), and the chin, throat, and infralabials remain cream colored. The darkened individuals are thereby easily separated from the melanistic form.

Blanchard and Blanchard (1940) studied the inheritance of melanism in *T. sirtalis sirtalis*. They found that melanism is caused by a single recessive gene; possibly this is the case in *T. radix*, although the presence of specimens intermediate between the normal phenotype and the heavily melanistic phenotype (Smith 1961; Morris 1975) suggests the existence of multiple alleles or multiple factors for melanism.

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Dr. P. W. Smith kindly brought the specimen to my attention, provided color notes on the fresh animal, and read the manuscript.

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OCCUPATION AND NATURAL STRATIGRAPHY IN THE CENTRAL ILLINOIS RIVER VALLEY: THE BEARDSTOWN TERRACE COMPLEX

Joseph Schuldenrein
University of Chicago

ABSTRACT

Paleo-ecological parameters for Archaic site occupation in the Central Illinois Valley were the object of geo-archeological investigations conducted in the course of contract archeology along the Illinois Waterway. Preliminary survey and testing, undertaken by a University of Illinois (Chicago Circle) team, established associations between alluvial sedimentary environments and occupation contexts. Detailed sediment testing was focused on the Otter Creek and Richardson sites to determine natural stratigraphy and evolutionary history of the Beardstown Terrace Group, a series of meltwater formations that probably documents the terminal episode of major fluvial sedimentation in the Valley. Basal sand-gravel matrices and overlying pedomorphic units were analyzed to elucidate both the nature of deposition and the chronological framework within which sequential morphogenetic change took place. The terrace complex is tentatively correlated with shoreline fluctuations in the Lake Michigan Basin and glacio-fluvial events in the Mississippi Valley, to derive a measure of geo-archeological contemporaneity with known early Archaic sites. Post-Woodfordian fluvial activity may explain both the limited distribution and restricted intra-site assemblages of Archaic complexes in the alluvial terraces and bottoms. The author cautions against overly inductive paleo-anthropological interpretations of archeological survey data in the riverine micro-environment.

INTRODUCTION

Initial research into the sedimentology and paleo-geography of the Beardstown Terrace Group began in the summer of 1974 when the University of Illinois (Chicago Circle) was contracted by the U.S. Army Corps of Engineers to conduct an archeological survey along the Illinois River

from the confluence of the Kankakee-Des Plaines rivers to Beardstown, Illinois. The research strategy employed by the surveyors included a series of extensive geomorphological tests for purposes of establishing landform correlations with the prehistoric proveniences of artifacts. The results of these investigations are presented elsewhere (Hall, Schuldenrein et al., 1974). As the paleo-ecological studies progressed it was decided that intensive sedimentological research was warranted at the Otter Creek site, NW1/4 NE1/4 NE1/4 sec. 28 T3N R3E Chandlerville (15') Quadrangle in the Central Illinois Valley (Fig. 1) since

1) it contained a significant scatter of artifacts;
2) the primary archeological cluster was concentrated on a sand ridge rising ca. 7' above the alluvium; and
3) the site was situated in a critical terrace setting that had produced a wealth of archeological material.

Initial fieldwork was geared primarily at establishing environmental parameters for the morphology of this sand ridge, specifically to determine its depositional vs. erosional origin, and to distinguish it as a point bar, aeolian, or terrace component of the alluvial eco-zone. Preliminary fieldwork consisted of detailed landform description and articulation of the micro-environmental components (i.e. sedimentary basins, backswamp depressions) of the surrounding riverine area. Sedimentological testing involved the extraction of two 2" core samples to depths of 12' at optimal sand ridge locales. These samples were analyzed for sedimentary, pedological, and stratigraphic association by a battery of chemical and mechanical tests. The results strongly suggested that the formation conformed to the late-Wisconsin Beardstown (T-1) terrace as described by Wanless (1957).

The chronological isolation of this particular terrace outcrop prompted an examination of the archeological correlates of the Beardstown Terrace Group in the Central Illinois Valley. Information supplied by Alan Harn (personal communication) indicated that 19 Beardstown Terrace sites ranging in temporal occupation from Archaic to Mississippian span the distance from Liverpool to Anderson Lake (Fig. 1), and that 14 of them feature primary Archaic components. Of the 30 Archaic sites known within the valley (i.e. below the uplands) 46.7% are located on the Beardstown surface. A systematic survey conducted by Munson and Harn (1966) on three prominent Beardstown outcrops suggests that ca. 40% of the total diagnostic point assemblage consisted of Archaic artifacts. At the time, the authors reported that "Prior to modern drainage ... the terraces were virtual islands surrounded by shallow lakes, swamps and marshes ..." (Munson and Harn, 1966:150). Subsequent survey undertaken by the same researchers in the Mississippi Valley indicated a similar intensity of Archaic occupation and site settlement patterning along the flanks of the corresponding T-1 Festus/Wood River Terrace (Munson and Harn, 1971), in the American Bottoms. The next step in the geo-archeological research was an attempt to formulate a more precise association of the terrace by means of diagnostic artifact types and spatio-temporal correlations of corresponding landforms.

Preliminary geomorphologic and morphostratigraphic correlations obtained through the analysis of the Otter Creek soil cores implied that a potentially productive interpretive parameter might be obtained by

studying the morphogenetic evolution of the late Wisconsinian Beardstown surfaces. A second set of investigations was therefore directed towards

1) ascertaining the stratigraphic position of the Beardstown within the alluvial micro-environment, and
2) establishing a relative chronology of sedimentary activity which would attest to the stabilization of depositional environments, as evidenced by the progression of Archaic cultural activity.

Fieldwork resumed in August, 1975, and involved the exposure of a north-south face of a gravel pit at the Richardson Site (Fv 1111) (Munson and Harn, 1966), 2 miles upstream from Otter Creek, in SE1/4 SE1/4 NW1/4 sec. 10 T3N R3E Havana (15') Quadrangle. The pit was profiled to a depth of 14' and we obtained a clear lateral exposure of horizontal sedimentary bedding that permitted reconstruction of the geomorphic sequence. Larger soil samples were taken here and were submitted to a wider variety of tests than the Otter Creek cores. The results of the two field seasons follow a brief synopsis of the evolution of the Beardstown Terrace group and its position in the Illinois River terrace chronology.

DEPOSITIONAL HISTORY OF THE BEARDSTOWN TERRACE

Wanless (1957) describes the Central Valley topography in terms of a glacial terrace sequence to the east and upland bluffs (Illinoian Till Plain) to the west. Four regional non-slackwater terraces have been identified and consist of outwash deposits of the Woodfordian-age Bloomington Moraine (Fig. 2). Wanless (1957) has not recorded detailed stratigraphic sections representative of either Manito, Havana, Bath, or Beardstown levels, but has postulated a two-stage, late Woodfordian degradational suite for the erosional surfaces of the higher downsloping Manito (550-490') and Havana (485-465') terraces. This was the result of turbulent Kankakee Torrent activity. The lower surfaces of the Bath (465-445') and the Beardstown (445-436') substages are attributed to separate episodes in the complex Lake Chicago sequence, with the downsloping Bath associated with erosion and the Beardstown a product of deposition, as documented by numerous meander scars on its surfaces. The following basic chronology is suggested (Willman and Frye, 1970, Willman, 1973):

Substage	Event	Occurrence	Terraces
Woodfordian	Kankakee Flood	c. 15,000-14,000 B.P.	Manito, Havana
Woodfordian-Valderan	Lake Chicago Activity	c. 14,000-9,000 B.P.	Bath, Beardstown

Precise dating for both the Kankakee Flood and Lake Chicago remains problematic, with the best information for the Flood deriving from a correlation with Thebes Gorge (Willman and Frye, 1970:35), and data pertaining to Lake Chicago levels obscured by arguments keying on the fluctuating stages and drainage patterns of the Lake Michigan Basin (Hough, 1958, 1966; Bretz, 1951, 1966), and the changing limit of the Valderan ice margin (Evenson, 1973) during the Woodfordian-Valderan interval.

With respect to the Beardstown, Root (1936: 214 ff.) offers an alternative evolutionary explanation, preferring a locational model to

'anless' sequential one. He refers to the Beardstown group as a series of bar-like sand-gravel depositions associated with various post-Kankakee Flood levels. In such a scheme, those surfaces immediately north of the Sangamaon River are Bath manifestations, while those farther upstream are Havana outcrops -- erosional -- and subject to significant episodes of lateral migration by the river in response to an unstable equilibrium engendered by variability in the Kankakee and Lake Chicago discharge regimes (Root, 1936: 220).

Most recent evidence (Butzer, personal communication, Schuldenrein, this paper) suggests that the general morphology of the Beardstown Terrace had been established by the onset of Two-Creekan times. Such a hypothesis assumes that the large proglacial lake basins at the Illinois River headwaters trapped most of the coarse bedload sediment and, in default of demonstrable major flood surges during the Valderan (post-Kankakee Torrent), must have resulted in a predominant regime of suspended load transport and sedimentation by about 12,500 B.P. This would correspond to a readjustment of the river channel from a braided to a meandering stream and favored a narrower, steeper floodplain gradient promoting incision. Butzer (personal communication) has argued on the basis of evidence from the Koster site that at least forty feet of downcutting is verified prior to the onset of a new aggradation cycle in the Lower Illinois Valley ca. 9000 B.P. In the Central Valley minor and localized periods of sedimentary activity, associated with the gentle relief of the Beardstown Terrace with respect to the floodplain have resulted in certain modifications of the uppermost stratigraphic units into Recent times.

Regardless of which interpretation is preferred, evidence documenting absolute chronologies in the Chicago Outlet region remains inadequate and controversial. The following presentation of the local stratigraphic data is offered against this backdrop of relative sequences and comparative correlations.

THE 1974 FIELD SEASON: AN OVERVIEW

Without the benefit of geomorphological maps for the Otter Creek site region all initial environmental information was gathered from U.S. Army 1' contour maps and direct site observations. Core samples were taken at three locations on the basis of distinctive features of the micro-environment as follows (Fig. 3):

1) on a known spoil bank to establish a control and meaningful datum (443.2');
2) at the peak of the ridge (444.3'); and
3) on a northeastern backswamp depression (444.1').

After preliminary descriptions of the colour, texture, consistence, and structure of the pedogenic and sedimentary units, the samples were submitted to a variety of tests.

A) X-Ray Diffraction, to identify the rock-stratigraphic units of the cores, the approximate origin of their channel sand distribution, and the clay mineral composition of the samples for sequence and continuity through the profile. The underlying principle of this analysis is that vertical grain size variation results from solution of carbonates, clay eluviation

and illuviation, disaggregation,and silicate decomposition (Willman et al., 1966). The test was of limited utility to the Otter Creek samples, which undoubtedly represented outwash deposits that were not as diagnostic as in situ, weathered sediments with stratigraphic implications (see Hall, Schuldenrein et al., 1974 for tables). The existing clay fraction did correspond chemically to weathered tills showing that:

1) Otter Creek cores 2 and 3 were related outwash redepositions as gauged by overall similarity in both percentage of clay expandables and constituent minerology.
2) the channel sands were derived from northeastern tills that were washed out and drained through the Illinois Valley; this is suggested by the relative predominance of illite.
3) extensive reworking and mineral composition ratios establish the outwash as Woodfordian.

On this basis the Illinois State Geological Survey, which kindly carried out the analyses, classifies the undisturbed Otter Creek sediments as Modern Soils of the Cahokia Alluvium or the Henry Formation, favoring the former (McKay, personal communication).

B) Chemical Tests, consisting of i) pH, to document the nature of local pedogenesis subsequent to initial deposition. This is a means of tracing the progression of soil processes and gauges the degree of geomorphic stability with the environment as indicated by the systematic evolution of the Modern Soil. ii) Chittick Carbonates - i.e. total carbonate determination - for examining the degree of leaching of calcareous sediments.

Summarily, the tests show that Otter Creek 2 displays a modified ABC profile characteristic of that outlined for regionally typical Gray-Brown Podzolics. The profile becomes more diagnostically zonal away from the river channel as both distance to areas of active flooding and elevation with respect to water table increases. From these data it appears that Otter Creek 3 is essentially a podzolic soil subject to a degree of seasonal inundation. It contains a transitional soil periodically affected by the hydromorphism of high groundwater conditions at times of high river level or accelerated local rainfall. The development of an enriched B-horizon, the key to sustained pedogenesis along the alluvium, would be augmented by a long-term lowering of the water table in drier periods associated with restricted lateral migration of floodwaters. This would favor deepening of the A-horizon as well as accelerate formation of a more characteristic B-horizon by preventing translocated minerals from filtering through the coarser sands into the groundwater.

DESCRIPTION OF THE SEDIMENTARY SEQUENCE AT RICHARDSON

In August, 1975, we returned to the field and examined a clean face of a gravel pit measuring 14' deep by 8' long at the Richardson site (Fv 1111), the largest of the Beardstown terraces reported by Munson and Harn in the 1966 survey. The open lateral exposures provided necessary stratigraphic and bedding information to corroborate preliminary identification of the Otter Creek site as a Beardstown Terrace outcrop. It also enabled the investigators to distinguish at what levels active sedimentation gave way to sustained pedogenesis.

Samples taken at Richardson were submitted to the following analyses: 1) pH; 2) X-Ray Diffraction; 3) Total and organic vs. inorganic carbon assay. These tests were run to compare the sedimentary suites at Richardson with those at Otter Creek. Additionally, the textural compositions of the strata were determined according to particle size grades by both wet sieve (for size grades > 37u) and hydrometer (for silts and clays) methods. On the basis of the individual unit grade size distributions, statistal parameters of sorting, skewing and kurtosis were calculated to assist in the identification of the sedimentary origins of the horizons (see Folk and Ward, 1957, Folk, 1974). The Richardson profile and graphic results are shown in Figs. 4 and 5.

A tentative stratigraphic sequence is presented here, as based on a synthesis of field observations and results of detailed laboratory investigations:

III Primary cross-bedded gravels - This zone extends in depth from 432.5' to 438.3' . Bedded gravelly sands comprise the predominant size grade with coarser gravels displaying a high degree of rounding. Unit N features a comparatively high organic carbon content (1.16%), exceeding even that of the present surface, considering the coarse grade. The basal sand-gravel strata generally feature significantly higher organic and inorganic content than the overlying horizons. Sediments of Zone III are largely bimodal and the most poorly sorted in the profile, due to the prominence of coarse sands. Folk and Ward (1957) suggest that such platykurtic (i.e. kurtosis values of 1.00) and asymmetrically skewed deposits attest to systematic mixing of sediment populations. Particle size distributions do not vary significantly with depth and those textural variations occurring in levels S, T, U and V represent localized accumulations of finer sands.

The interface between zones III and II marks an abrupt transition from primarily fine to caorse grades accompanied by negative skewness measures.

II Riverine and Fine Textured Deposits - Zone II ranges from 432.5' to 441.5' and constitutes the most complex sedimentary interval as it records alternate phases of lower and higher energy sedimentation with intermittent humification and even pedogenesis. Fluvial deposit H demarcates 2 subunits within this zone, the strata below characterized by mineral breakdown and weathering, while those above are largely depositional. Of the latter, deposit E is most prominent and delimits the base for the modern profile.

Primary sediment textures in the lower subunit (below H) are in the medium-fine sand ranges with varying percentages reflecting both agencies of transport and degrees of weathering. Strata K and H exhibit the widest variation in textural composition as both are alluvial accumulations, the former featuring a coarse sand component while the latter is a sandy silt. H is the more poorly sorted deposit with boundaries clearly defined. It is differentiated from the underlying I level by the latter's more developed subangular blocky structure, sticky texture, and clay humus content. Higher pH is also associated with a major accumulation of leached carbonates. K's coarser composition is similar, in fact, to that of the Zone III strata.

Sediments above H are distinguished by high organic content, slight calcareous presence, and a moderately weathered basal alluvial soil, unit E, a medium-coarse water-laid sand. It is the best sorted horizon in the sequence. In the upper subunit organic versus inorganic ratios are fairly constant from deposits C through E. Levels A, C and F are ferruginous and may be the hydromorphic correlates of the Otter Creek 3 core, occurring at 440', 3' higher than they do downstream, perhaps due to structural differentiation in terrace morphology between the two regions (river gradient change is negligible).

I Modern Pedogenesis - From 441.5' to 446.0', 5' of well developed soil has formed in the uppermost alluvial horizons. Illuvial clay content increases upward through X2 and Y2, though precise percentages are not, unfortunately, available for the latter. Sorting is very poor and all horizons in the zone are very finely skewed. The B2 is Cambic on the basis of the well developed subangular blocky soil structure and clay content. Textures are largely within the loamy medium to fine sand range with some silt. Organic matter concentration is highest in Z2 and diminishes to a minimum at the interface with zone II. Calcareous presence is minimal and pH variability is negligible. The surface soil supported a mixed weed-grass cover.

INTERPRETATION OF THE LOCAL BEARDSTOWN ALLUVIAL SEQUENCE

The Richardson sequence, as outlined above, consists of 3 distinct sediment bodies that may be broadly interpreted as follows:

The cross-bedded gravels of Zone III alternate with coarse sand lenses suggesting that this sedimentary unit primarily represents periodic reworking of glacial outwash initially deposited in the Illinois Valley by the Bloomington Valley train, as Wanless (1957:143-44) argued. Cross-bedding, however, generally results from scour and fill alternations with changes of velocity or direction of movement. Thus while the original Bloomington outwash was a glacio-fluvial deposit seasonal erosion and redistribution of the Michigan ice lobe during the summer ablation period may well have combined with some primary outwash and resulted in regional reworking of deposits. Sedimentary activity was further affected by other a-periodic events in glacier regimen and evolution of the proglacial lakes. There is also the possibility that the gravels document a scour-fill cycle initiated by torrential waters of the Fox River or Kankakee Torrent, overriding the boulder-studded dam built by the Bloomington Moraine at glacial Lake Illinois (Willman and Payne, 1942; Willman and Frye, 1970:34). At Richardson, then, the precise sedimentary origins of the cross-bedded levels could not be identified so that the regional versus local outwash correlations of the zone could not be determined. The relatively high percentages of organic matter in the strata suggest erosion of upstream surfaces, with humic matter subsequently "sealed" within the sand-gravel matrices. Intermittent formation of humic floodplain soils may also have taken place subsequent to episodic deposition but with little distinct horizonation (i.e. azonal). Thus, in unit N, while no indications of subsoil weathering or texture B characteristics are in evidence, a weak humic paleosol may be indicated.

Mixed sediment populations support the hypothesis that Zone III represents till-derived, but reworked outwash. The gravelly sands also contain relatively high percentages of illite specifically diagnostic of till origins from the northern Illinois Valley (Frye et al., 1968). It is proposed that the fluvial regime at this time was that of a shallow braided stream carrying a predominantly sandy to gravelly bedload. Meltwater activity was periodic, reflecting annual peak discharges in the wake of large-scale summer ablation during surges of the Woodfordian retreat. Episodic readvances may have been responsible for occasional breaching of proglacial lakes that formed behind the Valparaiso moraine complex. Thus, the abundance of outwash components suggests that Zone III documents the major terminal glacio-fluvial discharge carried through the Illinois Valley.

The critical level in Zone II is H which records an alluviation featuring a comparatively fine-textured bedload and differentiates the lower subunit - a graded "B" solum - from the upper floodplain soils. Levels I and J, displaying clay translocation, concentration of illuvial sesquioxides, and a significant redistribution of carbonates, may represent an eroded lower B-Ca horizon that was subject to episodic reworking by inundation. Hence the H/I and K/J interfaces may be truncated relict surfaces, originally overlain by humic A and poorly developed B horizons that had been weathered in situ and/or eroded by formerly active floodwaters. Levels H through J possibly record a period of environmental stabilization. This is mirrored initially by the high montmorrillonite contents of these deposits which may be attributed to accelerated loess accumulations on the terrace surface (Glass, personal communication). A subsequent paleoclimatic shift, to seasonally moister conditions, would have resulted in B horizon deepening, as the soil assumed a podsolic character, and diminished periodicity of flooding. These Late Beardstown developments may be an expression of increased filtering of discharge through successive proglacial lake basins. Finer sediments attest to overbank accretion and higher proportion of suspended sediment. This could have occurred in the later stages of Lake Chicago during the transition to Two-Creekan times.

Whether H and K actually represent two distinct surfaces is difficult to ascertain, but the fact that K has such a low organic concentration and that the overlying I marks a major drop off in expandables, would argue that stabilization occurred in H and the relatively weathered K and J levels may actually be the lower B horizon. The precise character of the B is difficult to categorize as the uppermost portions of it have been eroded and the depth of leaching cannot be determined. It may be Cambic, as there is clearly a redistribution of carbonates, significant oxidation, and reasonably strong subsoil development.

The upper subunit, featuring coarser sands, is built on a mixed loess outwash surface that formed the parent material for the subsequent E level soil development, perhaps at horizon J with least organic matter and highest silt content. E probably documents a sustained time interval with a relatively stable alluvial regime. It is succeeded by the Modern Soil Profile. Pedogenesis at Richardson is more advanced than it is at Otter Creek, displaying a deep but non-acidic organic A1 horizon and a three stage B level development, underlain by a transitional (B)C.

We suggest that at least 2 (possibly 3) former surfaces are recorded in the Richardson sedimentary suite at levels H and M (and N?). It is significant to note that according to the statistical parameters both H and M as well as the present surface Z2 exhibited the strongest bimodal distributions, as suggested by the platykurtic curves (Folk, 1974:48).

REGIONAL MORPHOGENESIS: A PROVISIONAL RECONSTRUCTION

The Richardson site exposure offers the primary local stratigraphic backdrop against which a morphogenetic hypothesis can be presented for the Central Illinois Valley T-1 sequence. Basically it describes a three-stage model beginning with a terminal meltwater deposition, succeeded by a gradual trend towards environmental equilibrium, and culminating in the development of the Modern Soil at an elevation of 441.5'. It was possible, then to isolate trends in environmental dynamism and obtain perspectives on ecological parameters of site occupation. While these manifestations are evident at Richardson, it is instructive to speculate whether similar sedimentary processes are evident farther downstream, by examining the spatial distributions, morphologies, and geological contexts of other Beardstown alluvial outcrops.

In differentiating the Beardstown Terrace complex from the adjacent T-2, T-3 and T-4 terraces one could argue, on spatial and morphological grounds, that the discontinuous but widespread distribution of the Beardstowns is in marked contrast with the elongate patterned array of the higher surfaces. This could be explained by lateral facies variation between channel sands and finer flood silts, or it could be attributed to the sinuosity and shifts of younger channels that ultimately dissected the Beardstown floodplain and subsequently created a new floodplain topography in Holocene times. Altogether meandering tendencies and sinuosity tend to increase downstream and may be attributed to a diminished sediment load with decreasing quantities of bedload material (Schumm, 1972). In the Beardstown sequence the succession of downstream terrace depositions associated with increasingly fine sediments resulted in a more subdued floodplain topography increasingly prone to overbank accretion of flood silts. This is suggested at Otter Creek by:

1) finer grade sizes in the cores;
2) the relatively lower elevations at which the T-1 formation occurs; in fact, in the case of Otter Creek 3, relief above the alluvium is so marginal that overbanking and natural levee formation appear to be incipient sedimentary processes.

However, the downstream outcrops are patterned along a southwesterly axis aligned with the meander belt, attesting to their common depositional origin as part of the Beardstown T-1 system. Finer textured clay-silt sediments conform technically to the Cahokia Alluvium, while the coarser Otter Creek 2 and Richardson sands and gravels could theoretically be equated with Henry Formation, according to rock-stratigraphic criteria outlined for late-Wisconsin sediments (Willman and Frye, 1970; Willman, 1973). It is possible, however, that the Otter Creek 3 backswamp deposits merely record seasonal inundations of

Cahokia Alluvium over Henry Sands. There is no question that the surface and margins of the Beardstown outcrops have been eroded and subject to varying degrees of redeposition. In this context it is just possible that the uppermost horizons of Beardstown Terrace surfaces of low relief may actually correspond to T-O alluvial accumulations on their slopes grading onto the floodplain in some sectors of the valley. It is more probable, as a general explanation, however, that Zone I represents terminal flood silts that form an integral part of the Beardstown alluvial complex, and that the Modern Soil profile began development as soon as the surface became relatively stable. A similar aggradational sequence of coarse to fine facies is apparent in the terminal Pleistocene Deer Plain Terrace at the mouth of the Illinois Valley (see Rubey, 1952, Butzer, in press).

Such an argument finds support in the subsequent alluvial history of the Valley. As indicated above, floodplain incision by 60 feet or more took place during Two-Creekan times, ca. 12,5000-11,000 B.P. in response to a less competent stream with higher suspended load and may be attributed to a major paleoclimatic shift to warmer and drier conditions. Subsequent readjustments included a rapidly aggrading floodplain, strong seasonality, increased competence, and depositions of higher proportions of coarser sediment intermediate in texture between that of the Wisconsin outwash terraces and the modern floodplain. Butzer (in press) dates this interval to a few centuries prior to 9000 B.P. in the Lower Illinois Valley. Assuming similar trends in fluvial activity for the Central Valley, the major terminal episode for the evolution of the Beardstown Terrace level would correlate with the Calumet beach stage and renewed accretion would coincide with Farrand's (1969, personal communication) postulated interval for the lowering of the Michigan basin to the early Lake Chippewa level.

Along broader lines the late Wisconsin activity in the Illinois Valley may be linked with events in the Middle Mississippi. This is shown by the diagram depicting shoreline drops in the Lake Agassiz and Lake Michigan basins, associated with the Upper-Middle Mississippi and Illinois Valley drainageways respectively (Fig. 6). Data presented is gathered from Elson (1967:76), Matsch and Wright (1967), and Willman (1971), and we caution that absolute chronological associations are tenuous due to absolute dating problems and discrepancies in the correlations of even local sequences. It does appear that incremental drops in level within the two river systems do co-vary, at least on a broad scale. Leighton, in dating the glacio-fluvial Mississippi Valley Modoc deposits attributes the origin of the late Pleistocene sediments to the Lake Algonquin stage at 9,500-8,500 B.P. (Fowler, 1959). This would tie in generally with the Lake Algonquin shoreline drop indicated by Willman (1971), and it also fits in with an episode of major environmental discontinuity postulated by Wendland and Bryson (1974) at 9,500 B.P. on the basis of a statistical sampling of geologic and paleobotanic radiocarbon dates.

ARCHEOLOGICAL IMPLICATIONS OF THE PALEO-ECOLOGICAL OBSERVATIONS

The Beardstown Terrace Group exhibits an overall distribution of Middle Archaic through Mississippian assemblages. Interestingly, the southern terraces are generally correlated with later assemblages than their northern counterparts. The lower downstream terraces are and have been more subject to flood-silt accumulation. Furthermore, T-1 surfaces downstream are often indistinguishable, topographically, from the active alluvium, allowing greater possibilities for Holocene erosion and local accretion or redeposition at the margin of the functional floodplain. Thus, the paucity of diagnostic Early-Mid Archaic components on either the Beardstown (T-1) or floodplain (T-0) stages supports the hypothesis that the functional floodplain between 10,000 and 5,000 B.P. was at a much lower level, even though accumulating at a rapid rate. Butzer (in press) has estimated the rate of sedimentation of the Peyton Colluvium in the Koster tributary valley of the Lower Illinois to be c.20"/century during Horizons 12 and 11 (ca. 8750 - 8200 B.P.), and 6"/ century for the time span between Horizons 11 through 6 (8200-500 B.P.). In the adjacent Mississippi Valley, Willman and Frye (1970:37) report an upright tree dated to 6600 B.P. at a depth of 50 feet below the present surface. The implication here is that the record of pre-late Archaic occupation of the floodplain (if indeed there is one!) is buried beneath tens of feet of sandy to silty sediments.

In the Central Valley area, later Archaic sites begin to proliferate contemporaneously on the alluvial surfaces as well as on the Beardstowns and 26.7% (8) of all Archaic sites were found on the Qal formation. This suggests two possibilities. First, the areas mapped "Qal" (see Wanless, 1957: Plate 3) may actually include eroded Beardstown formations and were not classified accordingly because they were at similar elevations as the "Qbn". Second, parts of the "Qal" surface consist of "higher bottoms", i.e. sandy stretches of higher ground related to the mid-Holocene floodplain known as the Sand Ridge Terrace in the Lower Illinois Valley (see Fig. 7). In either case detailed geomorphological mapping, sedimentological tests, and correlations with soil maps should be able to establish the identity of once preferred site locales. Two sites in the Central Valley are especially significant in this regard, as they occur in the Thompson Lake "sand ridge". Summarily, the early to mid Holocene alluviation may well have buried or destroyed Paleo-Indian and Early Archaic sites on the lowest Beardstown outcrops, i.e. selectively in the southern area of Beardstown exposures, where lateral accretion of finer sediments may have been more active.

Subsequent flooding at the Sand Ridge Terrace level (+2M) began to stabilize after 5,000 B.P., it appears, and came to a halt by 2800 B.P. (Butzer, in press). Munson (1974) has noted a contemporaneous aggradational sequence for the Middle Mississippi Valley. Struever (1968) has documented the widespread distribution of Late Archaic/Early Woodland Black Sand settlements along such "floodplain sand ridges" for the Lower Illinois. Similar locational factors may have applied in the Central Valley for these transitional populations, suggesting parallel patterns of exploitation of river-margin habitats (Munson and Harn, 1971, Griffin, 1968). The channels in question were braided with high bedload content, on the basis of sandy and lenticular texture along the Illinois (Butzer, in press),

while the numerous meander scars on the Beardstown surfaces referred to by Wanless (1957:23) attest to a similar fluvial regime farther upstream.

By approximately 2500 B.P. the Illinois River appears to have incised its bed once again and returned to a meandering pattern with convex floodplain and dominantly suspended sedimentation. This may relate to a re-establishment of moister conditions and a less periodic discharge curve co-inciding with both the close of the Altithermal and a lowering of Lake Michigan (Larsen, 1973: Fig. 7). Such evidence may corroborate Griffin's (1961:714) hypothesis for Late Archaic cultural expansion in conjunction with ameliorating climatic trends.

CONCLUSIONS

The geo-chronological arguments presented above offer several possibilities bearing on the prehistoric occupation of the alluvial micro-environment. Perhaps the most important of these derive from the dating of the final terrace deposition and the onset of aggradation of the present floodplain. Assuming that the general morphology of the Beardstown Terrace had been established by Woodfordian times, the overall absence of diagnostic Paleo-Indian (Clovis) and Early Archaic assemblages is <u>not</u> a function of wide-scale Wisconsinan activity in the Valley. Such an explanation is at variance with that offered by Munson (1974) who has postulated a mid-Valderan deposition of the Festus (T-1) Terrace in the Mississippi Valley on artifact typological grounds. Thus, it is suggested that the absence of Clovis points and the presence of the tightly dated Dalton-Meserve points indicated a range of 10,000-9,000 B.P. for terminal Festus deposition. Munson himself (personal communication) has noted that finds of several late Paleo-Indian points have come to his attention from the Beardstown Terraces, suggesting at least the possibility that the fluted point hunters traversed the area. The fact that these represent isolated finds is inconclusive, as most Paleo-Indian sites in the Midwest have been recorded on scanty evidence.

It is proposed here that the lack of diagnostic indicators attesting to the presence of early cultures in the Central Illinois River Valley reflects on 1) local Holocene sediment reworking, and 2) cultural/subsistence strategies that were oriented toward upland biomes.

If we accept the initiation of Holocene conditions to coincide with a renewed aggradation of the floodplain ca. 9000 B.P., it is clear that pre-Mid Archaic assemblages would be obliterated by sandy-silty fill on Qal surfaces and differentially eroded and reworked at the Qbn (Beardstown) level. Stabilization by about 5000 B.P. at the approximate elevation ofthe present floodplain fits in with the widespread distribution of diagnostic Mid/Late Archaic Matanza and Raddatz side-motched points reported for the area (Munson and Harn, 1966), i.e. on Qal-Qbn surfaces.

Given the relatively early (12,000 B.P.) date advanced for the evolution of the Beardstown surfaces, it would appear that even major

episodes of alluvial activity at the present floodplain level, i.e. after 5000 B.P., would not have destroyed all traces of earlier cultural activity unless the riverine micro-environment proved an unattractive habitat prior to Mid-Archaic times. Backswamp and low-lying marshy-sloughs provided seasonal sustenance to the specialized economies that had developed only by the Late Archaic. On the other hand, the exploitation of large Pleistocene herd mammals preferring higher elevation prairie habitats is documented up to 8000 B.P. (Wright, 1974:13) and this period marks the end of accelerated alluvial aggradation in the Central Valley bottoms. It may be inferred then, that shortly after this period Archaic peoples were occupying sites that are presently exposed. Whether this points to a general demographic change associated with increased exploitation of aquatic resources remains problematic.

The transition from the Big Game hunting economy to the more varied subsistence base offered by the mesic terrace environments may be given geomorphological support, if we assume the utilization of a more specialized set of adaptations suggested by recognizable Mid-Archaic assemblages on the Beardstown outcrops ca. 5000 B.P. Cook(personal communication) has indicated that the period of maximum popularity of Matanzas points was 5500-4800 B.P. in the Lower Valley.

The parameters of geo-archeological stratigraphic correlation in the Central Illinois Valley are still questionable given the lack of stratified Archaic sites and absence of datable materials. The present study has attempted to outline the geomorphic history of the alluvial environment by documenting the period from terminal meltwater deposition to the onset of ecological stabilization and present floodplain utilization as suggested for later Archaic times. It can be inferred that the latter interval represented a protracted period subsequent to the Zone I deposition, perhaps in line with Butzer's Koster stratigraphy. It may have been initiated during the Woodfordian-Two Creekan transition on the T-1, and followed by renewed activity on the present floodplain. Munson and Harn's (1966) Raddatz and Matanzas side-notched points imply a reasonably extensive Mid-Archaic occupation in the alluvial micro-environment. On archeological grounds it is impossible to advance more convincing arguments until the spatio-temporal distributions of these typologies are more definitely established. This is especially true for the riverine micro-environment where short-term and seasonal environmental periodicity mitigated against the extrapolation of intra-assemblage components to examine inter-assemblage variability from differential scatters of surface materials.

ACKNOWLEDGEMENTS

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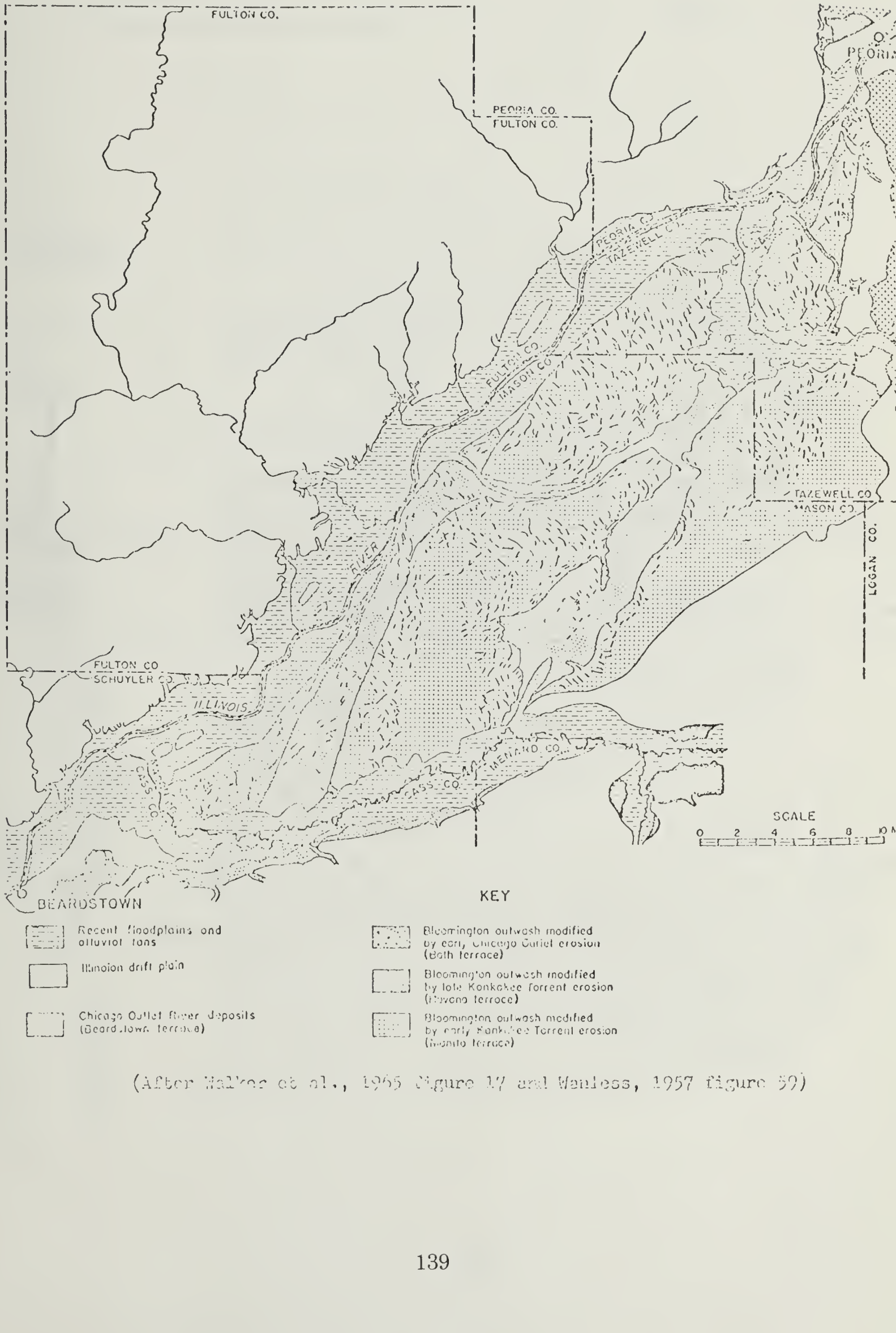
FIGURE 1 MAP OF CENTRAL ILLINOIS VALLEY

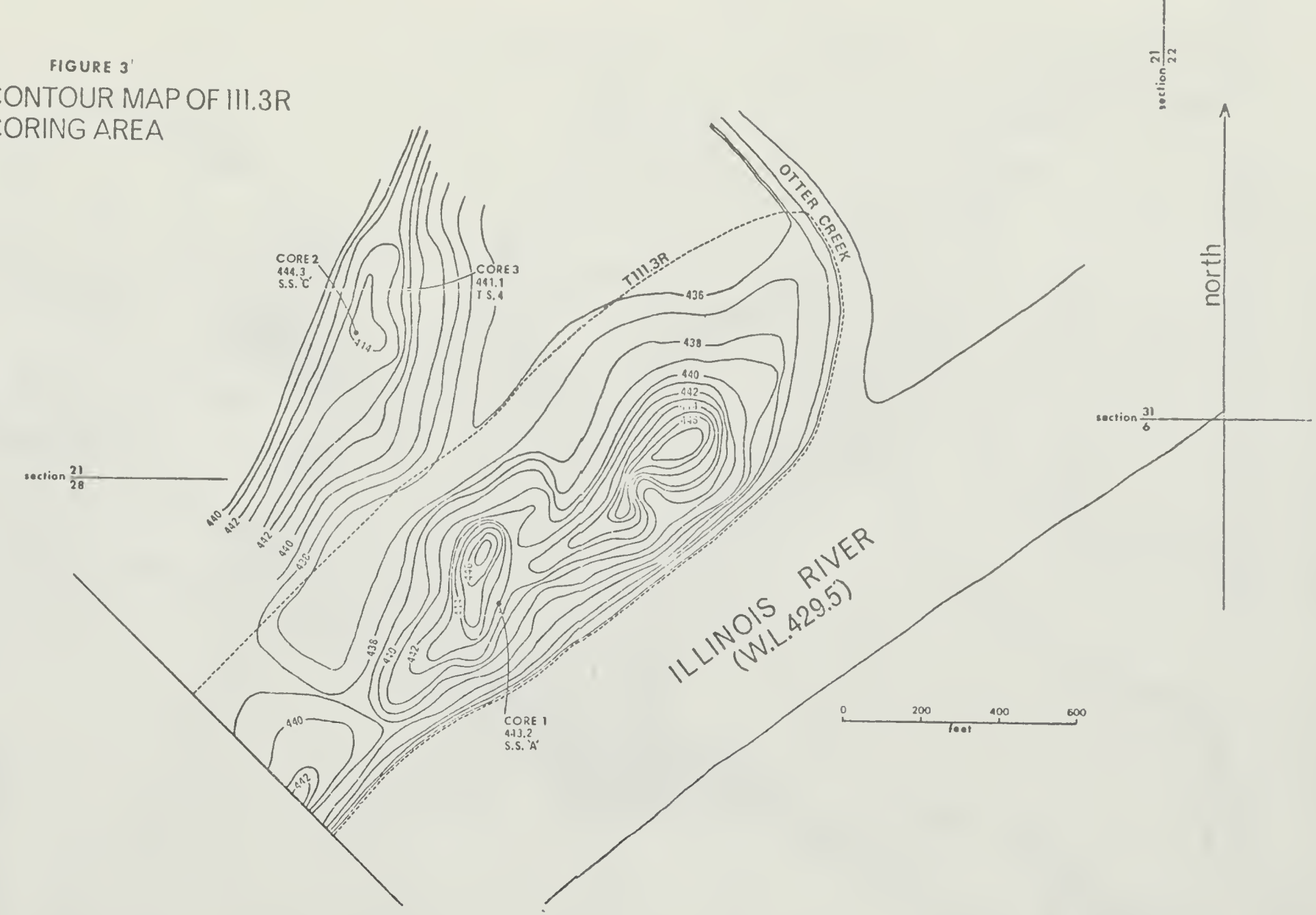
FIGURE 2 DISTRIBUTION OF TERRACES IN THE MIDDLE-LOWER ILLINOIS VALLEY



(After Walker et al., 1965 figure 17 and Wanless, 1957 figure 59)

FIGURE 3'

CONTOUR MAP OF III.3R
CORING AREA



GENERALIZED PROFILE
OF CORING AREA

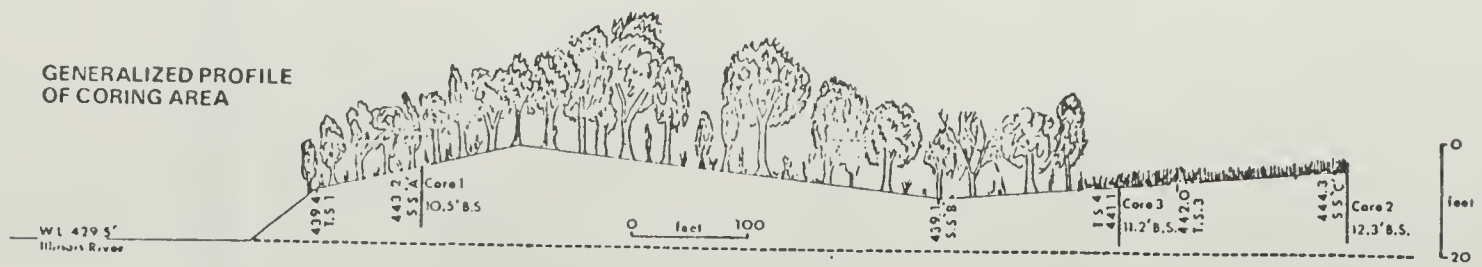


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FIGURE 4

PROFILE OF RICHARDSON SITE SECTION

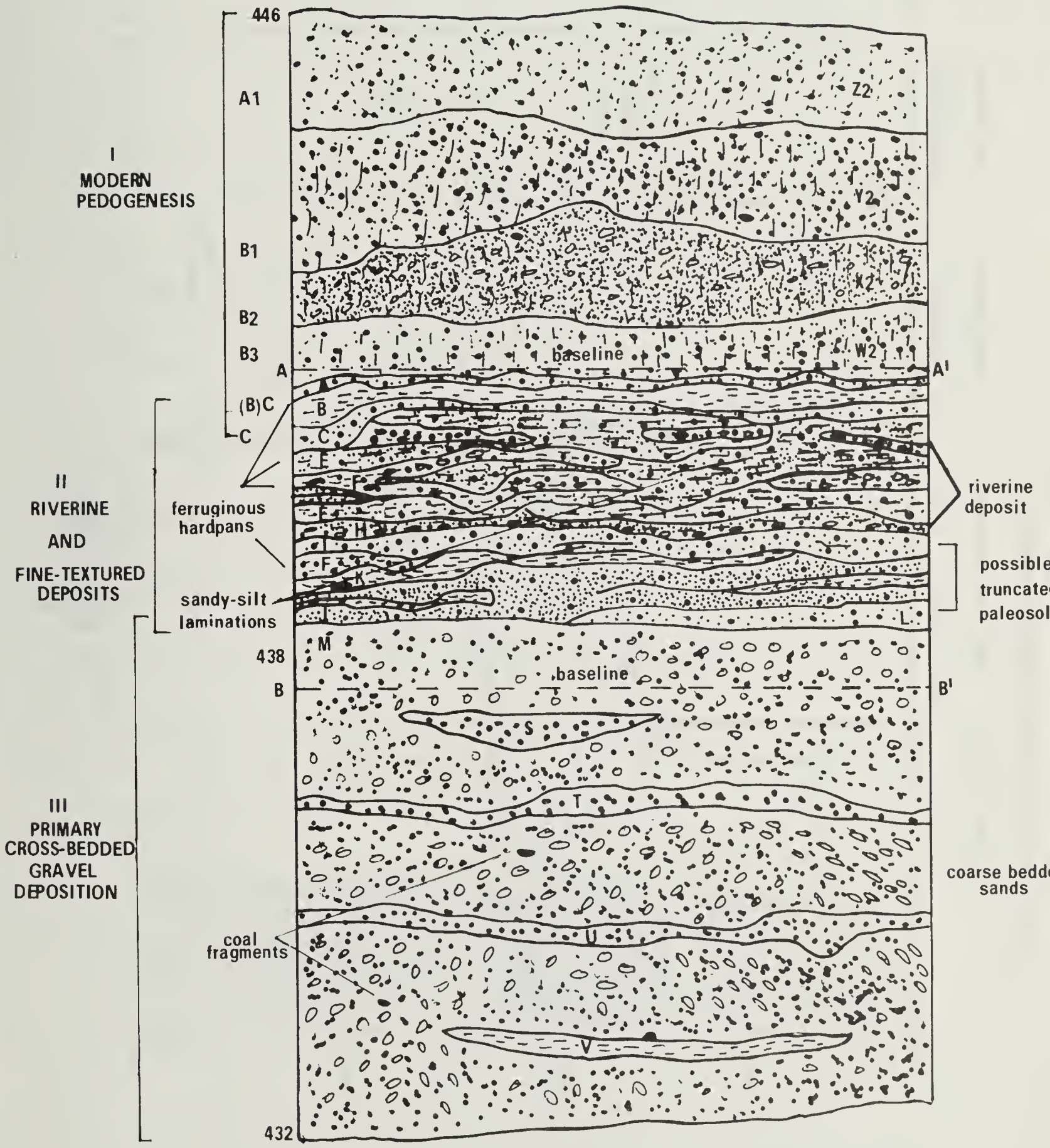


FIGURE 5

ANALYTICAL RESULTS OF THE RICHARDSON SEQUENCE

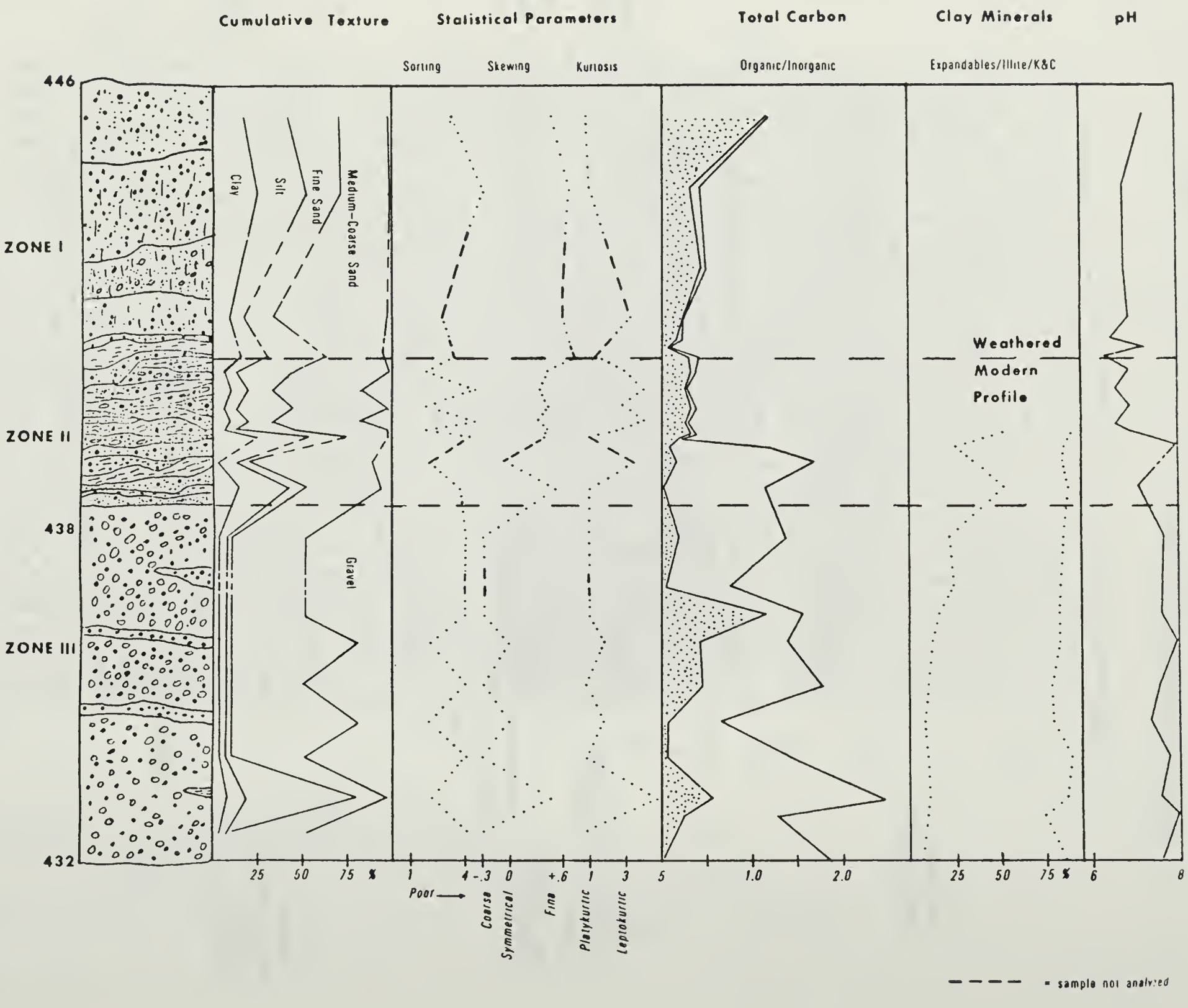


FIGURE 6

ELEVATION SHIFTS IN LAKE AGASSIZ AND MICHIGAN SHORELINES

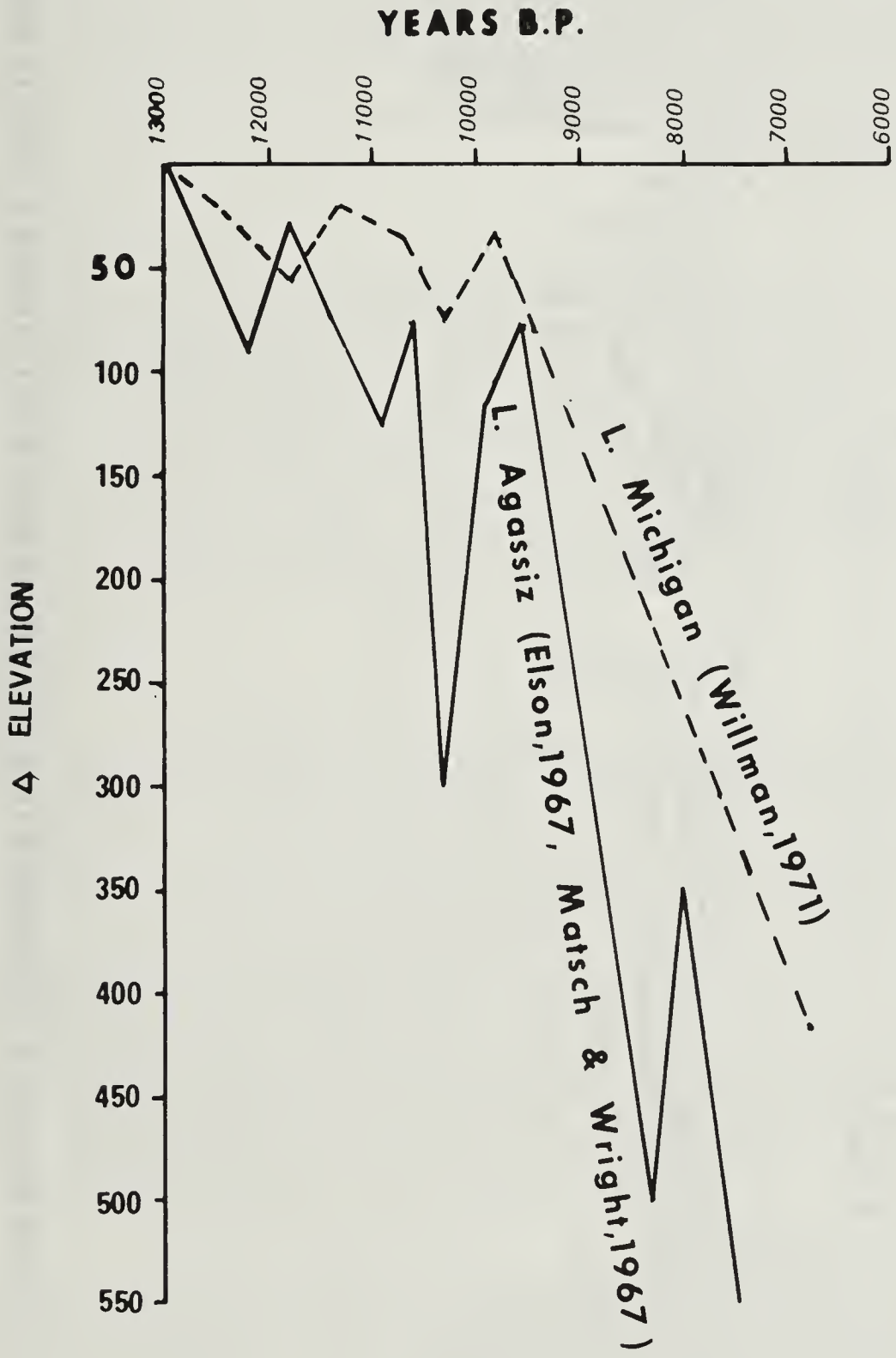
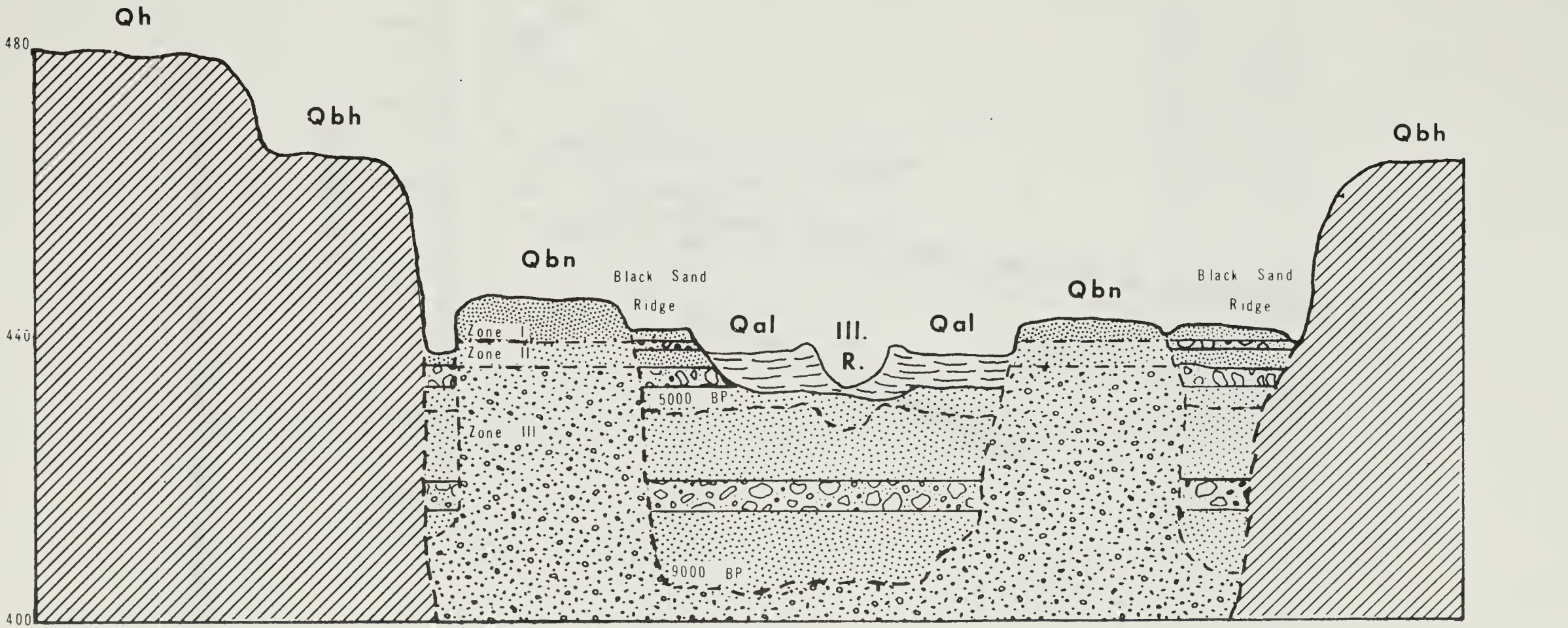


FIGURE 7 GENERALIZED PROFILE OF CENTRAL ILLINOIS FLOODPLAIN ENVIRONMENT



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PRELIMINARY INVESTIGATION OF A LARGE FLORA DEPOSIT FOUND IN PIT 11, PEABODY COAL COMPANY MINE

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ABSTRACT

A large number of carbon residue plant megafossils, characteristic of the middle Pennsylvanian Period, were discovered in a layer of Francis Creek Shale just above the Colchester (No. 2) Coal. In the over 600 specimens collected, ferns, pteridosperms, cordatales, and sphenopsids were identified, with an abundance of stems. Based on this data, a reconstruction of the paleoenvironment in which these flora were deposited suggests the terrestrial portion of a river delta.

INTRODUCTION

The Francis Creek Shale, a member of the Carbondale Formation, is exposed at several locations throughout western and north-central Illinois. This shale, as described by Smith (1970), overlies the Colchester (No. 2) Coal and varies in thickness from 0 to 80 feet. Its composition consists of fine grained sediment ranging in size from clay to fine sand with occasional mica present. Although in most locations the Francis Creek is generally considered a fossil-poor shale, the exposures at the Peabody Coal Company Mine near Braidwood, Illinois have produced some of the world's best specimens of middle Pennsylvanian flora and fauna. These famed Mazon Creek fossils are principally found within siderite concretions, but occasionally carbon residue fossils are found in layers within the shale. This carbon residue form of fossilization is considered relatively rare, although known to occur throughout the shale above the No. 2 Coal (Shabica, 1970).

In the present study, over 600 fragmented carbon residue plant fossils were collected from an area between ramps 2 and 3 directly across from the highwall in Pit 11 (fig. 1). The field collections were made in April, 1974 at a time when operations were in progress to fill in Pit 11 and eventually close down the mine. The specific location of find was in a spoil area recently uncovered by the shovel, and consequently the shale was very fresh and moist. This fact made preservation of the delicate fossil material possible. Subsequent return to the site revealed that it

had been buried beneath tons of spoil material, making future specimen discovery impossible.

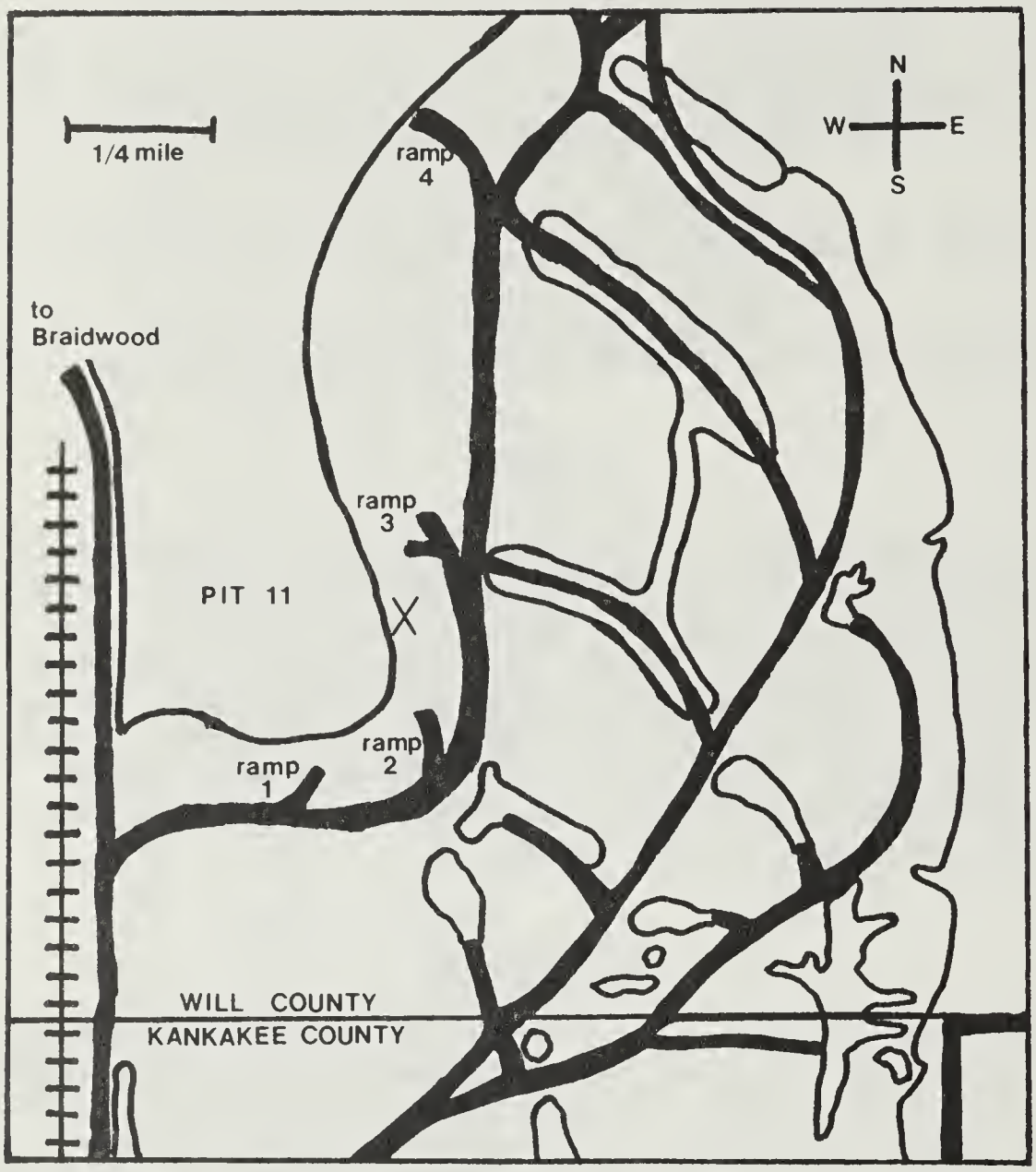

fig. 1. Location of Plant Megafossils Recovered in This Study.

RESULTS

In this preliminary investigation of the fossils found at this location, the predominant flora consist of ferns, pteridosperms, trees and their parts (Table 1). The ferns occur as fragments ranging from complete fronds to individual pinnules with an abundance of associated stems (fig. 2). Trees were primarily represented by leaves and fragments of branches (stems) and bark. Pinnularia was also found in abundance. The identification of the various genera was based on comparison to the descriptions of Darrah (1970), Janssen (1965), and Langford (1958, 1963). Noteably absent in this collection are faunal remains. Although early forms of insect and animal life were common at that time, no evidence of terrestrial or marine fauna was found.

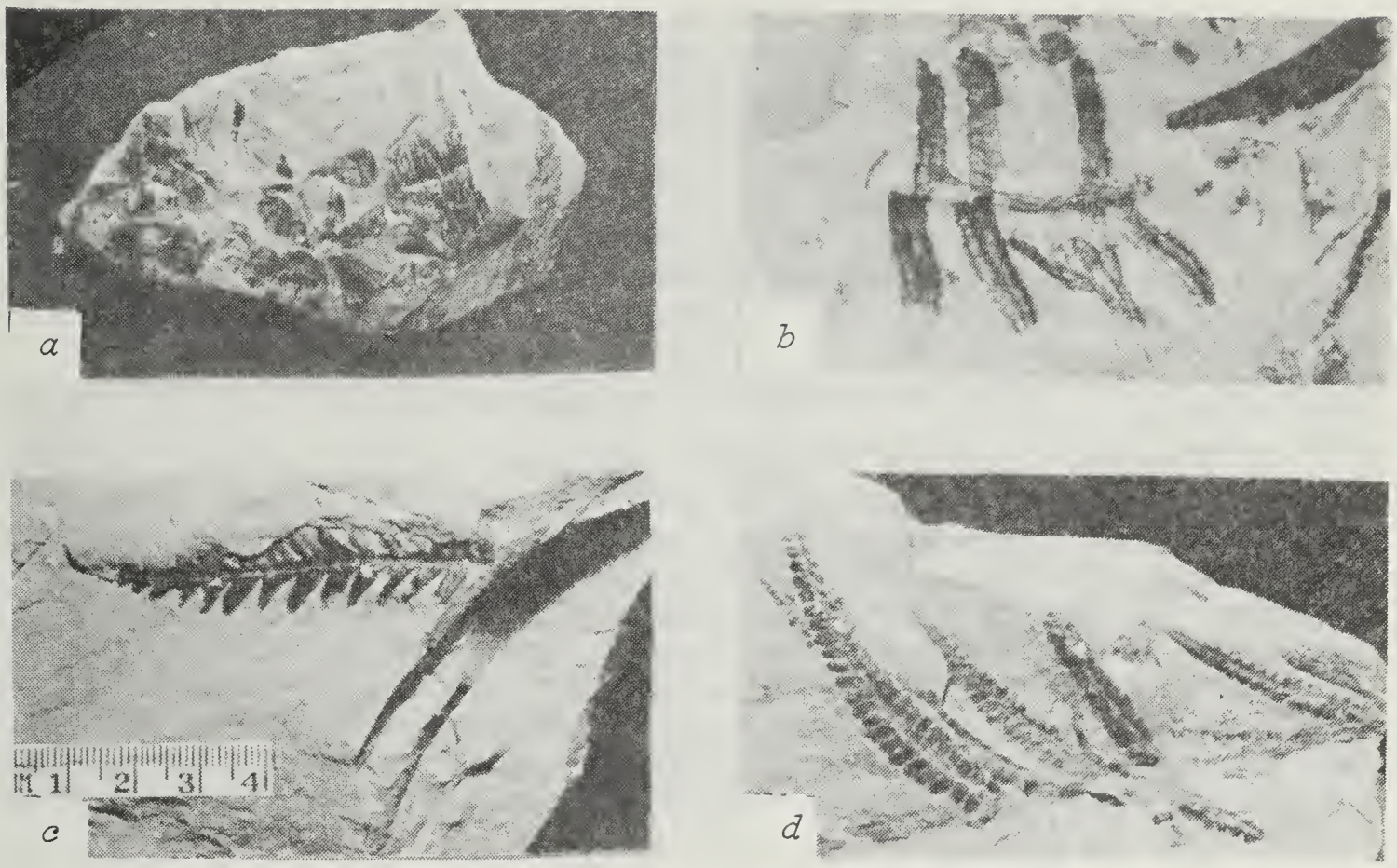

fig. 2. *(a)* Sphenophylum majus *(center) with a* Calamites *stem (right); (b) fragment of* Asterotheca*; (c) frond of* Pecopteris*, genera* Sentenbergea pennaeformis*; (d) several fronds of* Pecopteris*, genera* Asterotheca arborescens.

Statistically, ferns in general account for more than half the total number of specimens identified in this study, and they were classified according to their generic names within the Filicinae and pteridosperm. The most abundant and representative of the Filicinae are the specimens of Pecopteris and its varying species. Alethopteris and its related species are the dominant pteridosperm, accounting for nearly twenty percent of the total number of identified specimens. The remaining fossils that were identified are the various forms of trees and related parts. Evidence for lycopsids was found in several small fragments of bark from Lepidodendron, with the characteristic diamond-shaped leaf scars clearly visible. Calamites, Annularia, and Sphenophyllum were the only species of Sphenopsids identified. The presence of Cordaites in large numbers is somewhat surprising, considering that they are usually associated with upland areas.

DISCUSSION

Considering the data obtained in this study, a reconstruction of the paleoenvironment in which these fossils were deposited is made possible. The large number of ferns and sphenopsids clearly suggest a swampy lowland area where this type of flora was abundant. Peppers and Pfefferkorn (1970) consider the association of pteridosperm, ferns, and sphenopsids as representative of a levee-floodplain environment. Based on the numbers of each genera reported in this study, a floodplain type of environment seems most probable, but an apparent contradiction is evident in the abundance of Cordaites. As compared to the distribution of flora reported in Table 2, the percentages obtained in this study correspond quite well. Obvious exception is the differing percentages of Cordaites and pteridosperms.

Assuming a typical floodplain environment, these apparent anomalies, combined with the layered nature of the flora deposits, suggest seasonal accumulations of debris washed downstream during periods of heavy rainfall and flooding. This would explain the abundance of Cordaites and pteridosperms which were both common to the uplands. The fragmented nature of the fossils also offers additional support for extensive transportation and a distant point of origin. Those genera which do correspond to the distribution data reported in the previous studies (Table 2) probably represent the indigenous flora of the floodplain. The fact that no marine fauna was found further suggests that this depositional area was located a considerable distance from the sea.

Table 1. Distribution of specimens according to form genera.

LYCOPSIDS		FILICINAE	
Lepidodendron	9	Asterotheca	27
Lepidophyllum	11	Caulopteris	1 (?)
Sigillaria	2	Crossotheca	1
		Dactylotheca	1
SPHENOPSIDS		Dicksonites	1
Annularia	18	Pecopteris	47
Calamites	17	Ptychocarpus	6
Sphenophyllum	17	Renaultia	12
		Senftenbergia	13
PTERIDOSPERMS		CORDAITES	
Alethopteris	101	Cordaites	72
Diplothmama	1		
Mariopteris	3	PINULARIA & STEMS	Abundant
Neuropteris	41		

Table 2. Distribution in percent of the flora of the Francis Creek Shale. (Modification of Peppers and Pfefferkorn, 1970)

Plant Group	Plant Megafossils (Francis Creek Shale)				
	1 Janssen 1946 (%)	2 Stewart 1950 (%)	3 ISGS Collection (%)	AVG. (1, 2, 3) (%)	Sipiera and Korbus, 1976 (%)
Lycopsids	6	7	14	9	5
Sphenospsids	20	11	17	16	22
Ferns	26	48	24	32.7	27
Pteridosperms	44	34	44	40.7	36
Cordaites	2	0.3	0.5	0.9	18
Others	2	-	0.5	-	-

CONCLUSION

During the Pennsylvanian Period, the paleoenvironment of the Coal Region of Illinois was characterized by regular transgressions of the sea which would inundate the lowland areas and bury all traces of life beneath layers of silt, sand, and mud. The Braidwood area in particular resembled a typical deltaic environment with a river flowing in from the northeast. For the particular site where the fossils of this study were found, the depositional environment suggested by the distribution of flora, corresponds well to the terrestrial portion of a delta plain as described by Shabica (1970).

ACKNOWLEDGEMENT

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MOOSE TRIPLETS ON ISLE ROYALE

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Abstract.-- A sighting of moose triplets on Isle Royale, Michigan is reported.

Triplets in moose (Alces alces) are extremely unusual, therefore our observation of this phenomenon on Isle Royale, Michigan is recorded. On 3 June 1974 we observed a cow moose closely followed by three similar-sized calves swimming in Tobin Harbor between the shore and a small wooded island nearly 50 m distant. Upon reaching the shore the cow and three calves moved into brush and were lost from view.

Triple ovulations or embryos have been confirmed in a very small proportion of moose females (Simkin, 1965; Pavlov and Yazan, 1967; Markgren, 1969), but the authors are aware of only one previous sighting of similar-sized triplets associated with one cow (Hosley and Glaser, 1952). The occurrence of triplets on Isle Royale is particularly unusual since previous investigators (Murie, 1934; Mech, 1966) have found no evidence of triplets, or triple ovulations or embryos, and perhaps due to the less than optimum food supply for the island's moose population, even the number of twinning observations on Isle Royale has declined significantly over the past decade (R. Peterson, per. com.).

The possibility that the triplets seen may be a result of adoption of one or more calves cannot be excluded, although adoption in moose is very infrequent. In the late 1920's Mr. Peter Edisen observed three calves associated with one cow on Isle Royale, however, one calf was significantly larger indicating the likelihood that it had joined a cow with a set of twins (R. Peterson, per. com.). It should be emphasized that the three calves of the present observation were all of a very small similar size indicating recent birth.

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AN ANNOTATED LIST OF THE VASCULAR PLANTS OF SAND RIDGE STATE FOREST, MASON COUNTY, ILLINOIS

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ABSTRACT

During a three year study, 459 species of vascular plants were recorded from Sand Ridge State Forest, Mason County, Illinois. The habitats, abundances, and flower phenologies are given where possible. The families with the most species were the Compositae (65), the Graminae (64), and Leguminosae (32). Plants adapted to xeric conditions were very common throughout the area.

INTRODUCTION

Sandy soil, characteristic of Sand Ridge State Forest (formerly Mason State Forest) and much of the Illinois River Valley, is responsible for the edaphic conditions which have promoted the establishment of many xeric species, including invaders from the western plains. Meltwater rivers of glaciers originally deposited this sand in late Wisconsin and Holocene times, and transportation by wind increased its distribution (Willman and Frye, 1970). The action of wind continues today and is readily apparent in the form of blowouts and dunes.

The biology of Illinois sand areas received general descriptive treatment by Hart and Gleason (1907). Shortly thereafter Gleason (1910) defined the floral formations and associations of the inland sand areas of Illinois. Vestal (1913) added an associational study which emphasized the fauna. No other salient literature exists on Illinois sand areas although Evers (1955) complemented the earlier work with a monograph on the hill prairies of Illinois. The generally dry conditions of hill prairies and sand prairies permit a substantial species overlap.

Unfortunately, many of the floral elements, both species and associations, described by Gleason (1910) are absent or scarce at Sand Ridge State Forest. This may be partially explained by the small area (ca. 6400 acres), the lowered water table, and man's activities. Prominent examples of human disturbances in this century include clearing of the forest, cultivation of the land, and planting of pines and other exotics which grow well on sand. The numerous plantings and fencerows have decreased the amount of wind-blown

sand and, as a consequence, have altered delicately balanced successional processes. On the other hand, plowed firelanes, abandoned farms, and other disturbed areas have provided habitats in several stages of succession. Nonetheless, these artificially cycled areas show little resemblance to Gleason's (1910) associations. The frequencies of many species apparently have changed, and numerous species, commonly considered weeds, have colonized disturbed sites.

The objectives of this study were to (1) identify the vascular plants, (2) define their habitat(s), (3) assess their abundance, and (4) record their flowering times. Hopefully, this compilation will assist scientists and naturalists who visit the area and will stimulate others to seek out additional species and subsequently update this account.

METHODS

This survey was conducted weekly from late March-October of 1974-75 along Sand Ridge Road. Other areas (e.g., mesic woods, pine plantations, and ponds) were occasionally examined during 1974-76 for highly local species which grow within state forest boundaries. Aquatics, grasses, sedges, and trees were recorded only in 1975. Additional records were obtained from the University of Illinois Herbarium.

Habitats: Sand Ridge State Forest consists primarily of disturbed sand prairie interdigitated with extensive oak woodlands and pine plantations. The habitat designations which follow are largely the products of convenience; nevertheless, most of the habitats are probably valid units.

Oak woods--forests dominated by Quercus spp., often with abundant Carya spp. The understory varies from Carex spp. and scattered herbs in the dry open areas to abundant shrubs, lianas, and mesophytic plants in the areas with more soil moisture and shade.

Clearings in woods--unforested patches surrounded by oak woods. The centers of depressed clearings (apparently interdunal) hold much leaf litter while more level ones usually have exposed sand. The perimeters characteristically abound with Carex spp.

Borders of woods--transition zones between the oak woods and prairie. Well shaded borders usually possess some characteristic species.

Pine plantations--pure stands of exotic pines planted throughout the area. Except in light gaps there is little or no development of an understory.

Prairie--fields, often containing brush piles, not cultivated for 10 or more years or of unknown history. The species composition may vary from predominantly lichens, Opuntia compressa (Salisb.) Macbr., and Panicum spp. to an almost pure cover of bunch grasses.

Abandoned fields--fields apparently cultivated in the past 2-10 years, usually for the planting of pines. Good index species are Asclepias syriaca L., Aster spp., Erigeron spp., Solidago spp., and Strophostyles spp.

Margins of blowouts--the zone of moving, sparsely vegetated sand at the perimeters of blowouts. Typical species include Aristida spp., Carex muhlenbergii Schk., and Panicum pseudopubescens Nash.

Blowouts--hollows formed by the wind. They may become sparsely vegetated in late summer.

Firelanes--annually plowed firebreaks.

Fencerows--shrubby borders to fields which often harbor mesic species.

Ponds--woodland or man-made depressions filled with water.

Pond margins--zones of wet sand and detritus within 0-3 m of standing water. These areas suffer periodic inundation.

Moist areas near ponds--zones, generally within 2-40 m of ponds, which support a variety of ferns, Salix spp., Viola spp., and others, including mats of Polytrichum.

Roadsides--areas, generally within 5 m of roads, which because of runoff and disturbances have a rather characteristic weedy flora. The best development of this habitat category can be seen along the roads at the boundaries of the state forest. Remnants of Gleason's (1910) bunch grass association are sometimes present.

Disturbed areas--a very general designation for disturbed sites other than roadsides, for example, the campgrounds and construction sites. Naturally, such areas share many species with roadsides.

Whenever a species exhibited an obvious preference within a habitat (e.g., shaded roadside or exposed roadside), the information is included in the annotation. Furthermore, only the typical habitats are mentioned for the abundant species. Where only herbarium records were available, the habitat description was taken from the label of the herbarium sheet.

Abundance: The categories refer strictly to species abundances within habitats and not to abundances of the habitats.

Uncommon--4 or fewer plants encountered during the study.

Occasional--several or more plants occurred in 2-4 disjunct habitat patches, not necessarily of the same type.

Common--moderate numbers of plants found in at least one-half of the habitat patches of the listed type(s).

Very common--plants were abundant in most habitat patches of the listed type(s).

The species determinations were based on the keys or descriptions in Jones (1963), Marcks (1974), Mohlenbrock (1975), and Rehder (1940). Voucher specimens of all collections will be deposited in the University of Illinois Herbarium (Urbana, Illinois).

ANNOTATED CHECKLIST

A total of 459 species were identified from Sand Ridge State Forest. The best represented families were the Compositae (65 spp.), the Graminae (64 spp.), and the Leguminosae (32 spp.). With the exception of cultivated plants, there were 22 county records (marked with *) which were not listed in Jones and Bell (1974).

PTERIDOPHYTA

EQUISETACEAE

Equisetum hyemale L. Margins of blowouts and roadsides. Occasional.

OPHIOGLOSSACEAE

Botrychium dissectum Spreng. Moist areas near ponds. Occasional. Sept.-Oct.

B. virginianum (L.) Sw. Well shaded areas in oak woods. Occasional. May-June.

POLYPODIACEAE

Asplenium platyneuron (L.) Oakes. Moist areas near ponds and pine plantations. Common. July-Aug.

Onoclea sensibilis L. Moist areas near ponds. Occasional. Aug.-Oct.

Pteridium aquilinum (L.) Kuhn. Southern slopes of forested dunes in oak woods. Occasional.

Thelypteris palustris Schott. Moist areas near ponds. Common. June-Aug.

Woodsia obtusa (Spreng.) Torr. Pine plantations. Occasional.

SPERMATOPHYTA

Gymnospermae

CUPRESSACEAE

Juniperus virginiana L. Planted.

PINACEAE

Pinus banksiana Lamb. Planted.
P. densiflora Sieb. & Zucc. Planted
P. resinosa Ait. Planted.
P. rigida Mill. Planted.

P. strobus L. Planted
P. sylvestris L. Planted. Apr.-May.
P. thunbergii Parl. Planted.
P. virginiana Mill. Planted. Apr.-May.
Pseudotsuga menziesii (Mirb.) Franco. Planted in oak woods.

TAXODIACEAE

Taxodium distichum (L.) Rich. Ponds and their margins. Planted

Angiospermae

ACANTHACEAE

Ruellia humilis Nutt. Prairie with abundant bunch grass. Occasional. July-Aug.

ACERACEAE

Acer negundo L. Abandoned fields, fencerows, and roadsides. Occasional. Mar.-Apr.
A. saccharinum L. Oak woods. Uncommon.

AIZOACEAE

Mollugo verticillata L. Abandoned fields and firelanes. Very common. June-Sept.

AMARANTHACEAE

Amaranthus albus L. Abandoned fields and firelanes. Very common. July-Aug.
A. hybridus L. Roadsides and other disturbed areas. Uncommon. Aug.-Sept.
Froelichia floridana (Nutt.) Moq. Abandoned fields and firelanes. Very common. June-Sept.

ANACARDIACEAE

Rhus aromatica Ait. [incl. R. arenaria (Greene) G.N. Jones]. Fencerows, oak woods, and prairie. Very common. Mar.-May.
R. glabra L. Borders of woods and fencerows. Occasional. June-July.
*R. typhina L. Borders of woods. Occasional. June.
Toxicodendron radicans (L.) Kuntze. Fencerows and oak woods. Common. May-June.

APOCYNACEAE

Apocynum cannabinum L. Abandoned fields and oak woods. Common. June-Aug.

ASCLEPIADACEAE

Ampelamus albidus (Nutt.) Britt. Fencerows. Uncommon.
Asclepias amplexicaulis Sm. Abandoned fields, firelanes, and margins of blowouts. Common. May-June.
A. incarnata L. Moist areas near ponds. Occasional. July-Sept.
A. syriaca L. Abandoned fields and roadsides. Very common. June-Aug.
A. tuberosa L. Abandoned fields, firelanes, prairie, and roadsides. Common. June-Sept.
A. verticillata L. Oak woods and roadsides. Common. June-Aug.
A. viridiflora Raf. Sparsely vegetated sand at margin of blowout. Uncommon. Collected in flower on 15 June 1975 by P.W. Price.

BERBERIDACEAE

Podophyllum petatum L. Well shaded, moist areas of oak woods. Occasional. Apr.-May.

BETULACEAE

Alnus glutinosa (L.) Gaertn. Planted in moist area near the pond on the Black Oak Nature Trail. Mar.-Apr.
Betula nigra L. Planted in same area as species listed above.
Corylus americana Walt. Oak woods. Occasional. Mar.

BIGNONIACEAE

Campsis radicans (L.) Seem. Fencerows and disturbed areas. Occasional. July-Aug.
Catalpa speciosa Warder. Roadsides. Occasional. May-June.

BORAGINACEAE

Cynoglossum officinale L. Roadsides. Uncommon. May-June.
Hackelia virginiana (L.) I.M. Johnston. Oak woods. Common. July-Aug.
Lithospermum arvense L. Disturbed areas. Uncommon. May-June.
L. caroliniense (Walt.) MacM. Firelanes, margins of blowouts, oak woods, prairie, and roadsides. Very common. Apr.-July.
L. incisum Lehm. Roadsides and other disturbed areas. Uncommon. May.
Mertensia virginica (L.) Pers. Oak woods. Uncommon. Apr.-May.

CACTACEAE

Opuntia compressa (Salisb.) Macbr. Oak woods, prairie, and roadsides. common. June-July.

CAMPANULACEAE

Campanula americana L. Well shaded areas in oak woods. Occasional. July-Sept.
Specularia perfoliata (L.) A. DC. Abandoned fields and prairie. Common. May-June.

CAPPARIDACEAE

Polanisia dodecandra (L.) DC. Prairie and disturbed areas. Occasional. July-Sept.

CAPRIFOLIACEAE

Lonicera maackii Maxim. Planted in moist area near pond on the Black Oak Nature Trail. May-June.

Sambucus canadensis L. Fencerows, moist areas in oak woods, and roadsides. Common. June-Aug.

Symphoricarpos orbiculatus Moench. Shaded roadsides. Occasional. Aug.

CARYOPHYLLACEAE

Cerastium vulgatum L. Disturbed areas. Common. Apr.-Aug.

Holosteum umbellatum L. Sides of paved roads. Occasional. Mar.-May.

Lychnis alba Mill. Roadsides and other disturbed areas. Occasional. May-July.

Paronychia canadensis (L.) Wood. Open oak woods. Very common. June-Aug.

P. fastigiata (Raf.) Fern. Open oak woods. Occasional.

Saponaria officinalis L. Roadsides. Occasional. June-Oct.

Silene antirrhina L. Firelanes and roadsides. Common. May-June.

*S. dichotoma Ehrh. Sandy soil. Collected in flower on 10 July 1960 by J.K. Bouseman.

S. stellata (L.) Ait. f. Borders of woods, under shrubs in fencerows, and shaded roadsides. Common. July-Aug.

Stellaria media (L.) Cyrillo. Disturbed areas and oak woods. Occasional. Apr.-June.

CELASTRACEAE

Celastrus scandens L. Fencerows and oak woods. Common. May-June.

Euonymus atropurpureus Jacq. Well shaded, moist areas in oak woods. Occasional. June-July.

CHENOPODIACEAE

Chenopodium album L. Abandoned fields, firelanes, and roadsides. Common. June-Sept.

C. hybridum L. Shaded roadsides and other disturbed areas. Occasional. June-Sept.

Cycloloma atriplicifolia (Spreng.) Coult. Abandoned fields, firelanes, and margins of blowouts. Very common. June-Aug.

Kochia scoparia (L.) Roth. Abandoned fields and roadsides. Uncommon.

CISTACEAE

Helianthemum bicknellii Fern. Open oak woods and the exposed borders. Occasional.

H. canadense (L.) Michx. Open oak woods. Common. May-June.

Lechea tenuifolia Michx. Open oak woods and disturbed areas. Occasional. July.

COMMELINACEAE

Commelina erecta L. Abandoned fields and firelanes. Common. June-Sept.
Tradescantia ohiensis Raf. Oak woods, prairie, and roadsides. Very common. May-Aug.

COMPOSITAE

Achillea millefolium L. Pine plantations and roadsides. Occasional. May-July.
Ambrosia artemisiifolia L. Firelanes and other disturbed areas. Common. July-Sept.
A. psilostachya DC. Abandoned fields, oak woods, and prairie. Common. July-Sept.
A. trifida L. Abandoned fields, firelanes, and roadsides. Very common. July-Sept.
Antennaria neglecta Greene. Slopes of forested dunes in oak woods. Uncommon. Apr.-May.
A. plantaginifolia (L.) Hook. Oak woods. Common. Apr.-May.
*Arctium minus (Hill) Bernh. Shaded roadsides and other disturbed areas. Occasional. July-Aug.
Artemisia caudata Michx. Firelanes and roadsides. Occasional. July-Aug.
Aster azureus Lindl. Open oak woods. Very common. Sept.-Oct.
A. ericoides L. Abandoned fields. Occasional. Aug.-Oct.
A. lateriflorus (L.) Britt. Open oak woods. Occasional. Sept.-Oct.
A. linariifolius L. Open oak woods. Uncommon.
A. ontarionis Wieg. Moist areas near ponds and shaded roadsides. Common. Aug.-Oct.
A. pilosus Willd. Abandoned fields and roadsides. Common. Aug.-Oct.
A. sagittifolius Wedem. Open oak woods. Occasional. Sept.-Oct.
A. simplex Willd. Moist areas near ponds and roadsides. Occasional. Aug.-Oct.
Bidens bipinnata L. Pine plantations. Occasional. July-Sept.
B. frondosa L. Moist areas near ponds. Occasional. Aug.-Oct.
Brickellia eupatorioides (L.) Shinners. Clearings in oak woods and open oak woods. Uncommon. July-Aug.
Cacalia atriplicifolia L. Oak woods and roadsides. Common. July-Sept.
*Carduus nutans L. Disturbed areas. Uncommon. June-July.
Chrysanthemum leucanthemum L. Roadsides and other disturbed areas. Occasional. June-July.
Chrysopsis camporum Greene. Roadsides and open oak woods. Very common. May-Oct.
Cirsium discolor (Muhl.) Spreng. Abandoned fields and roadsides. Common. Aug.-Sept.
C. vulgare (Savi) Tenore. Roadsides and other disturbed areas. Common. Aug.-Sept.
Coreopsis lanceolata L. Roadsides and adjacent prairie. Occasional. May-June.
C. palmata Nutt. Oak woods and shaded roadsides. Occasional. June-July.
Erechtites hieracifolia (L.) Raf. Oak woods. Common. Aug.-Sept.
Erigeron annuus (L.) Pers. Disturbed areas and open oak woods. Occasional. June-July.
E. canadensis L. Abandoned fields. Very common. July-Sept.

E. strigosus Muhl. Abandoned fields, open oak woods, and roadsides. Very common. May-Aug.

Eupatorium perfoliatum L. Moist areas near ponds. Occasional. Aug.-Sept.

E. rugosum Houtt. Oak woods. Very common. July-Oct.

E. serotinum Michx. Moist areas near ponds and pine plantations. Occasional. Aug.-Sept.

Gnaphalium obtusifolium L. Abandoned fields and prairie. Common. Aug.-Oct.

Helianthus annuus L. Planted in fields and escaped from cultivation. Occasional. July-Sept.

H. divaricatus L. Oak woods. Common. July-Sept.

H. hirsutus Raf. [incl. H. tuberosus L. and hybrids]. Oak woods and roadsides. July-Sept.

H. occidentalis Riddell. Borders of woods, clearings in woods, and roadsides. Occasional. July-Sept.

H. petiolaris Nutt. Firelanes and roadsides. Very common. June-Oct.

H. rigidus (Cass.) Desf. Borders of woods. Occasional. July-Sept.

H. strumosus L. [incl. hybrids]. Roadsides. Common. Aug.-Sept.

Heliopsis helianthoides (L.) Sweet. Oak woods and roadsides. Occasional. July-Sept.

Hieracium longipilum Torr. Open oak woods and their borders. Occasional. July-Sept.

H. scabrum Michx. Oak woods. Common. Aug.-Sept.

Krigia virginica (L.) Willd. Abandoned fields and exposed areas in the prairie and oak woods. Common. Apr.-July.

Lactuca canadensis L. Abandoned fields, oak woods, and roadsides. Common. July-Sept.

L. scariola L. Abandoned fields and roadsides. Common. July-Sept.

Liatris aspera Michx. Open oak woods, prairie, and roadsides. Common. Aug.-Sept.

Matricaria matricarioides (Less.) Porter. Disturbed areas. Occasional. May-July.

Ratibida pinnata (Vent.) Barnh. Roadsides. Occasional. June-July.

Rudbeckia hirta L. Prairie and shaded roadsides. Very common. June-Aug.

Senecio plattensis Nutt. Open oak woods, priarie, and roadsides. Very common. Apr.-May.

Solidago canadensis L. [incl. S. altissima L.]. Abandoned fields and moist areas near ponds. Common. July-Oct.

S. gigantea Ait. Abandoned fields. Occasional. Aug.-Sept.

S. graminifolia (L.) Salisb. [incl. S. media (Greene) Bush]. Borders of woods, moist areas near ponds, and prairie. Occasional. Aug.-Oct.

S. juncea Ait. Abandoned fields. Occasional. July-Aug.

S. nemoralis Ait. Open oak woods. Very common. Aug.-Oct.

S. speciosa Nutt. Open oak woods. Occasional. Aug.-Oct.

S. ulmifolia Muhl. Oak woods. Occasional. Aug.-Oct.

Taraxacum officinale Wiggers. Roadsides and other disturbed areas. Occasional. Mar.-Oct.

Tragopogon dubius Scop. Roadsides. Very common. May-Aug.

T. pratensis L. Roadsides and other disturbed areas. Occasional. May-July.

Vernonia missurica Raf. Moist areas near ponds. Common. Aug.-Sept.

*Xanthium strumarium L. Roadsides. Uncommon.

CONVOLVULACEAE

*Cuscuta cuspidata Engelm. Moist areas near ponds and roadsides. Parasitic on Compositae. Occasional. July-Sept.
Ipomoea hederacea Jacq. Abandoned fields. Common. July-Sept.
I. lacunosa L. Abandoned fields and fencerows. Occasional. July-Aug.

CORNACEAE

Cornus drummondi C.A. Meyer. Fencerows, oak woods, and isolated clones in prairie. Common. May-June.
C. florida L. Oak woods. Uncommon. Apr.-May.
C. racemosa Lam. Fencerows, oak woods, and isolated clones in prairie. Occasional. May-June.

CRUCIFERAE

*Alliaria petiolata (Bieb.) Car. & Gr. Well shaded roadsides and other disturbed areas. Occasional. Apr.-June.
Arabis canadensis L. Oak woods. Common. May-July.
Barbarea vulgaris R. Br. Roadsides and other disturbed areas. Occasional. Apr.-May.
Brassica nigra (L.) Koch. Roadsides. Uncommon.
Capsella bursa-pastoris (L.) Medic. Disturbed areas. Occasional. Apr.-June.
Descurainia pinnata (Walt.) Britt. Roadsides and other disturbed areas. Common. Apr.-May.
Draba reptans (Lam.) Fern. Abandoned fields and roadsides. Common. Apr.
Erysimum asperum (Nutt.) D C. Borders of woods, open oak woods, and roadsides. Very common. Apr.-July.
Hesperis matronalis L. Roadsides. Escaped from cultivation. Uncommon. May-June.
*Lepidium campestre (L.) R. Br. Disturbed areas. Occasional. May-July.
L. virginicum L. Abandoned fields, firelanes, and roadsides. Very common. Apr.-Oct.
Sisymbrium altissimum L. Roadsides. Occasional. May-July.
S. officinale (L.) Scop. Disturbed areas. Occasional. June-July.

CUCURBITACEAE

Sicyos angulatus L. Borders of woods. Occasional. Aug.-Sept.

CYPERACEAE

Bulbostylis capillaris (L.) C.B. Clarke. Shaded, moist areas in firelanes and moist areas near ponds. Occasional. June-July.
Carex blanda Dewey. Oak woods and shaded roadsides. Occasional. Apr.-May.
C. brevior (Dewey) Mack. Oak woods. Common. Apr.-May.
C. davisii Schw. & Torr. Oak woods and shaded roadsides. Occasional. Apr.-May.

C. lanuginosa Michx. Open oak woods and clearing in woods. Common. Apr.-May.

C. meadii Dewey. Open oak woods. Common. Apr.-May.

C. muhlenbergii Schk. Abandoned fields, margins of blowouts, and open oak woods. Very common. Apr.-May.

C. pensylvanica Lam. Open oak woods. Very common. Apr.-May.

C. scoparia Schk. Moist areas near ponds. Common. Apr.-May.

C. umbellata Schk. Margins of blowouts, sparsely vegetated areas in oak woods, and clearings in woods. Very common. Mar.-Apr.

C. vulpinoidea Michx. Disturbed areas. Uncommon. Apr.-May.

Cyperus erythrorhizos Muhl. Moist areas near ponds. Occasional.

C. esculentus L. Moist areas near ponds. Occasional.

C. grayioides Mohlenbrock. Firelanes and margins of blowouts. Occasional.

C. lupulinus (Spreng.) Marcks. [incl. hybrids and subspecies]. Abandoned fields, firelanes, and margins of blowouts. Very common. June-Aug.

C. schweinitzii Torr. Firelanes and margins of blowouts. Occasional.

Eleocharis acicularis (L.) Roem. & Schult. Pond margins. Common. Aug.-Sept.

E. obtusa (Willd.) Schult. Moist areas near ponds. Occasional. June-July.

Fimbristylis autumnalis (L.) Roem. & Schult. Pond margins. July-Aug.

Hemicarpha micrantha (Vahl) Pax. Pond margins. Common.

EBENACEAE

Diospyros virginiana L. Margin of small woodland pond. Uncommon.

ELAEAGNACEAE

Elaeagnus umbellata Thunb. Row plantings in numerous fields. Apr.-May.

EUPHORBIACEAE

Acalypha rhomboidea Raf. Shaded roadsides and other disturbed areas. Occasional.

Chamaesyce geyeri (Engelm.) Small. Firelanes and margins of blowouts. Common. July-Sept.

C. maculata (L.) Small. Firelanes and roadsides. Common. July-Sept.

C. supina (Raf.) Moldenke. Firelanes and roadsides. Common. June-Sept.

Croton glandulosus L. Firelanes and margins of blowouts. Common. June-Sept.

Crotonopsis linearis Michx. Abandoned fields, blowouts and their margins, and firelanes. Very common. June-Sept.

Euphorbia corollata L. Abandoned fields, prairie, and roadsides. Very common. June-Sept.

E. marginata Pursh. Roadsides. Uncommon. July-Aug.

Poinsettia dentata (Michx.) Small. Firelanes and other disturbed areas. Common. June-Sept.

FAGACEAE

Quercus marilandica Muench. [hybridizes with next species]. Codominate of oak woods. Very common. Apr.-May.
Q. velutina Lam. Codominant of oak woods. Very common. Apr.-May.

GERANIACEAE

Geranium carolinianum L. Firelanes and roadsides. Common. May-June.

GRAMINAE

Agropyron repens (L.) Beauv. Oak woods and pine plantations. Occasional. June-July.
Agrostis alba L. Oak woods. Occasional.
A. hyemalis (Walt.) BSP. Abandoned fields and roadsides. Common. June-July.
Andropogon furcatus Muhl. Prairie and roadsides. Common. Aug.-Sept.
A. scoparius Michx. Prairie and roadsides. Common. Aug.-Sept.
A. virginicus L. Disturbed areas and moist areas near ponds. Occasional. Sept.
Aristida desmantha Trin. & Rupr. Prairie without bunch grass. Occasional. July-Aug.
A. purpurascens Poir. Open oak woods. Occasional. Aug.
A. tuberculosa Nutt. Blowouts and their margins, clearings in woods, and disturbed areas. Very common. July-Aug.
Avena sativa L. Disturbed areas. Occasional. May-July.
Bouteloua hirsuta Lag. Margins of blowouts, clearings in woods, and sparsely vegetated areas in prairie. Occasional. Aug.-Sept.
*Bromus ciliatus L. Oak woods. Occasional.
B. inermis Leyss. Roadsides and other disturbed areas. Common. June-July.
*B. japonicus Thunb. Firelanes. Common. May-June.
B. tectorum L. Firelanes and other disturbed areas. Very common. May-June.
Calamovilfa longifolia (Hook.) Scribn. Margins of blowouts and roadsides. Occasional. July-Aug.
Cenchrus pauciflorus Benth. Firelanes and roadsides. Very common. July-Aug.
Dactylis glomerata L. Abandoned fields and roadsides. Occasional. May-June.
*Danthonia spicata (L.) Beauv. Open oak woods and roadsides. Occasional.
Digitaria filiformis (L.) Koel. Firelanes and roadsides. Common. Aug.-Sept.
D. ischaemum (Schreb.) Muhl. Firelanes and roadsides. Common. Aug-Sept.
D. sanguinalis (L.) Scop. Firelanes and roadsides. Very common. June-Sept.
Echinochloa crusgalli (L.) Beauv. Moist, disturbed areas and roadsides. Occasional. July-Aug.
Eleusine indica (L.) Gaertn. Roadsides and other disturbed areas. Occasional. July-Aug.
Elymus canadensis L. Borders of woods and roadsides. Common. June-July.

Eragrostis cilianensis (All.) Mosher. Roadsides. Common. July-Aug.
E. hypnoides (Lam.) BSP. Pond margins. Common.
E. pectinacea (Michx.) Nees. Roadsides. Common. June-Sept.
E. spectabilis (Pursh) Steud. Abandoned fields, prairie, and roadsides. Very common. July-Sept.
E. trichodes (Nutt.) Wood. Abandoned fields, prairie, and roadsides. Very common. July-Sept.
Festuca elatior L. Roadsides and other disturbed areas. Common. June-July.
F. octoflora Walt. Firelanes, roadsides, and other disturbed areas. Common. May.
Hordeum pusillum Nutt. Roadsides. Common. May-June.
Koeleria cristata (L.) Pers. Open oak woods and prairie. Occasional.
Leersia oryzoides (L.) Sw. Pond margins. Uncommon.
Leptoloma cognatum (Schult.) Chase. Abandoned fields and prairie. Very common. July-Sept.
*Muhlenbergia frondosa (Poir.) Fern. Moist, shaded roadsides and other disturbed areas. Occasional. Aug.-Sept.
M. racemosa (Michx.) BSP. Moist, shaded roadsides and other disturbed areas. Occasional. Aug.-Sept.
M. schreberi J.F. Gmel. Moist, shaded roadsides and other disturbed areas. Occasional. Aug.
Panicum capillare L. Moist areas near ponds and shaded roadsides. Occasional. July-Sept.
P. depauperatum Muhl. Open oak woods and prairie. Very common. June-July.
P. dichotomiflorum Michx. Roadsides along prairie. Occasional. Aug.-Sept.
P. huachucae Ashe. Moist areas near ponds, pine plantations, and shaded roadsides. Common. June-Aug.
P. oligosanthes Schult. [incl. P. scribnerianum Nash]. Prairie and open oak woods. Very common. June.
P. praecocius Hitchc. & Chase. Borders of woods and prairie. Occasional.
P. pseudopubescens Nash. Margins of blowouts. Very common. June-July.
P. virgatum L. Margins of blowouts and roadsides. Common. July-Sept.
Paspalum ciliatifolium Michx. [incl. P. pubescens Muhl. and P. stramineum Nash]. Firelanes and roadsides. Common. July-Sept.
Phleum pratense L. Abandoned fields and roadsides. Occasional. June-July.
*Poa annua L. Disturbed areas. Planted(?).
P. compressa L. Roadsides and other disturbed areas. Occasional. June.
P. pratensis L. Oak woods and roadsides. Very common. May.
*P. sylvestris Gray. Disturbed areas. Occasional. June-July.
Setaria faberii Herm. Abandoned fields, roadsides, and other disturbed areas. Common. June-Sept.
S. lutescens (Weigel) Hubb. Roadsides. Occasional.
S. viridis (L.) Beauv. Roadsides and other disturbed areas. Very common. June-July.
Sorghastrum nutans (L.) Nash. Prairie with other bunch grasses. Common. Aug.-Sept.
Sphenopholis obtusata (Michx.) Scribn. Prairie. Uncommon.

Sporobolus clandestinus (Biehler) Hitchc. Oak woods. Common. Aug.-Sept.
Stipa spartea Trin. Prairie and roadsides. Occasional. May.
Tridens flavus (L.) Hitchc. Shaded roadsides. Common. July-Sept.
Triplasis purpurea (Walt.) Chapm. Clearings in woods, firelanes, and sparsely vegetated areas in prairie. Occasional. Aug.-Sept.
Triticum aestivum L. Roadsides and other disturbed areas. Escaped from cultivation. Occasional. May-June.
Zea mays L. Roadsides. Escaped from cultivation.

HYDROPHYLLACEAE

Ellisia nyctelea L. Firelanes and other disturbed areas. Occasional. Apr.-May.

HYPERICACEAE

Hypericum mutilum L. Moist areas near ponds. Common. July-Sept.
H. perforatum L. Abandoned fields and roadsides. Occasional. June-Sept.
H. punctatum Lam. Firelanes and other disturbed areas. Occasional. July-Sept.

IRIDACEAE

Iris sp. Roadsides. Escaped from cultivation. Uncommon. May-June.
Sisyrinchium campestre Bickn. Abandoned fields, prairie, and roadsides. Occasional. Apr.-May.

JUGLANDACEAE

Carya ovalis (Wang.) Sarg. Oak woods. Common.
C. texana Buckl. Oak woods. Occasional.
C. tomentosa (Poir.) Nutt. Oak woods. Common.
Juglans nigra L. Oak woods and roadsides. Occasional. May.

JUNCACEAE

Juncus acuminatus Michx. Pond margins. Occasional. May-June.
J. interior Wieg. Shaded, disturbed areas. Occasional. May-June.
J. tenuis Willd. Shaded, disturbed areas. Occasional. May-June.

LABIATAE

Agastache nepetoides (L.) Kuntze. Well shaded, moist areas at borders of woods. Occasional. Aug.-Sept.
Hedeoma hispida Pursh. Roadsides. Occasional. May-July.
H. pulegioides (L.) Pers. Oak woods. Occasional. Aug.-Sept.
Lamium amplexicaule L. Roadsides. Occasional. Apr.-May.
Leonurus cardiaca L. Oak woods and shaded roadsides. Occasional. May-July.
Lycopus americanus Muhl. Moist areas near ponds. Common. July-Sept.
Monarda fistulosa L. Shaded roadsides and other disturbed areas. Occasional. June-Aug.

M. punctata L. Prairie with little bunch grass and roadsides. Very common. June-Sept.

Nepeta cataria L. Fencerows, oak woods, and pine plantations. Occasional. June-Sept.

Prunella vulgaris L. Moist, shaded roadsides. Occasional. July-Sept.

Pycnanthemum pilosum Nutt. Moist areas near ponds. Occasional. July-Sept.

Scutellaria lateriflora L. Moist areas near ponds. Occasional. July-Sept.

S. leonardi Epling. Oak woods. Occasional. June-July.

Teucrium canadense L. [incl. T. occidentale Gray]. Shaded borders of woods and roadsides. Common. June-Aug.

LAURACEAE

Sassafras albidum (Nutt.) Nees. Borders of woods and roadsides. Occasional. Apr.-May.

LEGUMINOSAE

Amorpha canescens Pursh. Open oak woods, clearings in woods, and prairie. Occasional. June-July.

Amphicarpa bracteata (L.) Fern. Oak woods. Common. Aug.-Sept.

Apios americana Medic. Moist areas near ponds. Occasional.

Astragalus distortus Torr. & Gray. Clearings in woods and prairie. Occasional. Apr.-May.

Baptisia leucophaea Nutt. Open oak woods. Common. May-June.

Cassia fasciculata Michx. Firelanes and roadsides. Very common. July-Oct.

C. marilandica L. Fencerows. Uncommon. July-Aug.

Cercis canadensis L. Oak woods. Uncommon. Mar.-Apr.

*Coronilla varia L. Roadside slopes, perhaps planted. June-Oct.

Crotalaria sagittalis L. Abandoned fields and disturbed areas. Occasional. July-Sept.

Desmodium glutinosum (Muhl.) Wood. Well shaded border of woods. Uncommon. July-Aug.

D. illinoense Gray. Open oak woods and roadsides. Very common. June-Aug.

D. paniculatum (L.) DC. Borders of oak woods. Uncommon. Aug.

D. sessilifolium (Torr.) Torr. & Gray. Oak woods. Common. Aug.-Sept.

Gleditsia triacanthos L. Oak woods. Uncommon.

Glycine max (L.) Merr. Roadsides. Escaped from cultivation.

Lespedeza capitata Michx. Prairie and roadsides. Common. Aug.-Sept.

L. stipulacea Maxim. Roadsides. Occasional. Aug.-Sept.

Medicago lupulina L. Roadsides and other disturbed areas. Common. May-Aug.

M. sativa L. Roadsides and planted in fields. Occasional. June-Aug.

Melilotus alba Desr. Abandoned fields and roadsides. Common. June-Sept.

M. officinalis (L.) Lam. Roadsides. Common. May-Aug.

Petalostemum candidum (Willd.) Michx. Prairie with abundant bunch grass. Uncommon. July.

P. purpureum (Vent.) Rydb. Sparsely vegetated areas in prairie. Uncommon. June-July.

Robinia pseudoacacia L. Planted. May-June.

Strophostyles helvola (L.) Ell. Abandoned fields and firelanes. Very common. July-Sept.

S. leiosperma (Torr. & Gray) Piper. Abandoned fields. Common. July-Sept.

Tephrosia virginiana (L.) Pers. Clearings in woods. Very common. June-July.

Trifolium hybridum L. Disturbed areas, planted in campgrounds. Common. May-Aug.

T. pratense L. Abandoned fields and roadsides. Common. May-Sept.

Vicia villosa Roth. Abandoned fields and roadsides. Occasional. May-July.

Vigna sinensis (L.) Endl. Sandy soil in oak woods. Collected on 13 Aug. 1949 by J.A. Steyermark.

LEMNACEAE

Lemna minor L. Ponds. Very common.

Spirodela polyrhiza (L.) Schleid. Ponds. Very common.

LILIACEAE

Allium vineale L. Abandoned fields and roadsides. Occasional. Apr.-May.

Asparagus officinalis L. Roadsides and other disturbed areas. Occasional. Apr.-June.

Polygonatum commutatum (Schult.) A. Dietr. Borders of woods and under shrubs in fencerows. Occasional. May-June.

Smilacina racemosa (L.) Desf. Oak woods. Occasional. May-June.

Smilax hispida Muhl. Fencerows and oak woods. Common. May.

LYTHRACEAE

Rotala ramosior (L.) Koehne. Pond margins. Occasional. July-Aug.

MALVACEAE

Callirhoe triangulata (Leavenw.) Gray. Prairies and roadsides. Common. July-Sept.

MELASTOMACEAE

Rhexia virginica L. Moist areas near ponds. Occasional. July-Sept.

MENISPERMACEAE

Menispermum canadense L. Well shaded areas in oak woods. Occasional. May-June.

MORACEAE

Cannabis sativa L. Roadsides and other disturbed areas. Common. July-Aug.

Maclura pomifera (Raf.) Schneider. Borders of woods and fencerows. Occasional. May.

Morus rubra L. Borders of woods and fencerows. Occasional. May.

NYCTAGINACEAE

Mirabilis nyctaginea (Michx.) MacM. Roadsides. Common. May-June.

OLEACEAE

Syringa vulgaris L. Persistent around abandoned farms. Occasional. Apr.-May.

ONAGRACEAE

Gaura biennis L. Roadsides. Common. July-Sept.

Ludwigia alternifolia L. Moist areas near ponds. Very common. June-Aug.

L. palustris (L.) Ell. Ponds and their margins. Common.

Oenothera biennis L. [incl. O. strigosa (Rydb.) Mack. & Bush]. Abandoned fields, moist areas near ponds, and oak woods. Occasional. July-Sept.

O. laciniata Hill. Abandoned fields, firelanes, and other disturbed areas. Common. May-July.

O. rhombipetala Nutt. Abandoned fields, firelanes, and roadsides. Very common. June-Sept.

ORCHIDACEAE

Spiranthes cernua (L.) Rich. Moist areas near ponds, particularly in Polytrichum mats. Occasional. Aug.-Sept.

OXALIDACEAE

Oxalis dillenii Jacq. Abandoned fields, roadsides, and other disturbed areas. Common. May-Sept.

O. stricta L. Moist areas near ponds and shaded roadsides. Occasional. June-Sept.

O. violacea L. Disturbed areas, firelanes, and oak woods. Common. Apr.-June.

PAPAVERACEAE

Corydalis micrantha (Engelm.) Gray. Abandoned fields and sparsely vegetated areas in prairie. Occasional. Apr.-May.

Dicentra cucullaria (L.) Bernh. Well shaded areas in oak woods. Uncommon. Apr.

PHYTOLACCACEAE

Phytolacca americana L. Oak woods, pine plantations, and shaded roadsides. Common. June-Sept.

PLANTAGINACEAE

Plantago aristata Michx. Roadsides. Occasional. June-July.
P. lanceolata L. Disturbed areas. Occasional. June-Sept.
P. purshii Roem. & Schult. Prairie with little bunch grass. Common. May-June.
P. rugelii Dcne. Shaded roadsides and other disturbed areas. Common. June-Sept.
P. virginica L. Roadsides. Occasional. May-June.

PLATANACEAE

Platanus occidentalis L. Borders of woods and roadsides. Occasional.

POLEMONIACEAE

Phlox bifida Beck. Oak woods. Very common. Mar.-May.

POLYGALACEAE

Polygala polygama Walt. Sparsely vegetated areas in abandoned fields and prairie. Uncommon. June.
P. sanguinea L. Moist areas near ponds. Common. July-Sept.

POLYGONACEAE

Fagopyrum esculentum Moench. Firelanes. Occasional. May-Sept.
*Polygonella articulata (L.) Meisn. Oak woods. Common. Aug.-Oct.
Polygonum aviculare L. Lanes in oak woods and roadsides. Occasional. June-Sept.
P. coccineum Muhl. Moist areas near ponds. Occasional.
P. convolvulus L. Fencerows and roadsides. Very common. June-Aug.
P. cristatum Engelm. & Gray. Borders of woods, fencerows, and roadsides. Common. July-Sept.
P. fluitans Eaton. Abandoned fields. Occasional. June-Sept.
P. pensylvanicum L. Moist areas near ponds and shaded roadsides. Occasional. July-Sept.
P. punctatum Ell. Ponds and their margins. Occasional. Aug.-Oct.
P. ramosissimum Michx. Open oak woods. Occasional. Aug.-Sept.
P. sagittatum L. Moist areas near ponds. Common. Aug.-Sept.
P. scandens L. Oak woods and roadsides. Common. July-Sept.
P. tenue Michx. Firelanes and sparsely vegetated areas in oak woods. Very common. July-Sept.
P. virginianum L. Shaded, moist areas in oak woods. Occasional. Aug.-Sept.
Rumex acetosella L. Abandoned fields, roadsides, and other disturbed areas. Common. May-Aug.

R. crispus L. Roadsides. Common. May-June.

PORTULACACEAE

Claytonia virginica L. Oak woods and shaded roadsides. Occasional. Mar.-May.
Portulaca oleracea L. Roadsides and other disturbed areas. Uncommon.
*Talinum rugospermum Holz. Clearings in woods. Common. June-Aug.

POTAMOGETONACEAE

Potamogeton diversifolius Raf. Ponds. Common. Aug.-Sept.

PRIMULACEAE

Androsace occidentalis Pursh. Abandoned fields and roadsides. Very common. Mar.-May.
Lysimachia lanceolata Walt. Moist areas near ponds and shaded roadsides. Occasional. June-July.

RANUNCULACEAE

Anemone caroliniana Walt. Exposed slopes at roadside. Occasional. Mar.-May.
A. cylindrica Gray. Oak woods. Common. June-July.
A. virginiana L. Oak woods. Common. June-July.
Aquilegia canadensis L. Shaded roadsides. Uncommon. May-June.
Ranunculus abortivus L. Disturbed areas and oak woods. Occasional. Mar.-June.

RHAMNACEAE

Ceanothus americanus L. Oak woods and prairie with little bunch grass. Common. June-July.

ROSACEAE

Agrimonia parviflora Ait. Moist areas near ponds and in oak woods. Occasional. July-Sept.
Fragaria virginiana Duch. Oak woods and roadsides. Common. Apr.-June.
Geum canadense Jacq. Oak woods and shaded roadsides. Common. May-July.
Malus ioensis (Wood) Britt. Moist areas near ponds and roadsides. Occasional. Apr.-May.
Potentilla monspeliensis L. Roadsides and other disturbed areas. Common. May-Sept.
P. recta L. Roadsides and other disturbed areas. Occasional. May-Aug.
P. simplex Michx. Moist areas near ponds and well shaded areas in oak woods. Common. Apr.-July.
Prunus lanata (Sudw.) Mack. & Bush. Fencerows and roadsides. Common. Apr.-May.
P. persica (L.) Batsch. Shaded roadsides. Uncommon.
P. serotina Ehrh. Pine plantations and roadsides. Common. May.

P. virginiana L. Abandoned fields, fencerows, and the roadsides. Occasional. Apr.-May.

Pyrus communis L. Shaded roadsides. Escaped from cultivation. Uncommon.

Rosa carolina L. Oak woods and their borders. Common. May-July.

*R. multiflora Thunb. Borders of woods and roadsides. Occasional. May-June.

R. palustris Marsh. Moist areas near ponds. Common. June-Aug.

Rubus allegheniensis Porter. Borders of woods and disturbed prairie near brush piles. Common. May-June.

R. flagellaris Willd. Moist areas near ponds. Common. June-July.

*R. hispidus L. Shaded borders of woods. Occasional.

R. occidentalis L. Fencerows and pine plantations. Occasional. May-June.

RUBIACEAE

Cephalanthus occidentalis L. Moist areas near ponds. Uncommon. July-Aug.

Diodia teres Walt. Abandoned fields and firelanes. Common. June-Sept.

Galium aparine L. Abandoned fields and oak woods. Common. May-June.

G. circaezans Michx. Oak woods. Occasional. June-July.

G. pilosum Ait. Oak woods. Common. June-Sept.

RUTACEAE

Ptelea trifoliata L. Borders of woods and roadsides. Occasional. May-June.

Zanthoxylum americanum Mill. Fencerows and oak woods. Common. Apr.

SALICACEAE

Populus deltoides Marsh. Moist areas near ponds and roadsides. Occasional. Apr.

*Salix eriocephala Michx. Ditches along paved roads. Uncommon. Apr.

S. humilis Marsh. Moist areas near ponds and prairie. Common. Mar.-Apr.

S. interior Rowlee. Moist areas near ponds and along paved roads. Occasional. Apr.-June.

S. nigra Marsh. Moist areas near ponds. Occasional. Apr.-May.

SANTALACEAE

Comandra umbellata (L.) Nutt. Open oak woods and prairie. Very common. May-June.

SAXIFRAGACEAE

Ribes missouriense Nutt. Oak woods. Very common. Apr.-May.

R. odoratum Wendl. Roadsides. Uncommon. Apr.

SCROPHULARIACEAE

Aureolaria grandiflora (Benth.) Pennell. Oak woods. Occasional. Aug.-Sept.
Linaria canadensis (L.) Dumort. Abandoned fields, firelanes, and sparsely vegetated areas in prairie. Very common. Apr.-June.
*L. dalmatica (L.) Mill. Open oak woods. Occasional. May-Sept.
Lindernia anagallidea (Michx.) Pennell. Pond margins. Common.
Penstemon pallidus Small. Oak woods. Very common. May-June.
Scrophularia lanceolata Pursh. Open oak woods and their borders. Common. May-July.
Verbascum thapsus L. Abandoned fields, oak woods, and roadsides. Common. June-Sept.
Veronica arvensis L. Abandoned fields and disturbed areas. Occasional. Apr.-June.
V. peregrina L. Abandoned fields, roadsides, and other disturbed areas. Common. Apr.-June.

SOLANACEAE

*Datura stramonium L. In planted fields of sunflowers. July-Sept.
Physalis heterophylla Nees. Abandoned fields and firelanes. Common. May-Aug.
P. virginiana Mill. Oak woods. Occasional. May-June.
Solanum carolinense L. Abandoned fields and disturbed areas. Occasional. June-Sept.
S. nigrum L. Oak woods and disturbed areas. Occasional. June-Oct.

TILIACEAE

Tilia americana L. Moist areas in oak woods. Occasional.

ULMACEAE

Celtis occidentalis L. Oak woods and roadsides. Occasional.
Ulmus americana L. Moist areas in oak woods and roadsides. Common. Mar.
U. rubra Muhl. Roadsides. Occasional.

UMBELLIFERAE

Cryptotaenia canadensis (L.) DC. Moist areas near ponds. Uncommon. June-July.
Daucus carota L. Roadsides and other disturbed areas. Common. June-Sept.
Osmorhiza longistylis (Torr.) DC. Oak woods. Uncommon. Apr.-May.
Pastinaca sativa L. Roadsides. Occasional. May-July.
Sanicula canadensis L. Well shaded areas in oak woods. Occasional. May-July.

URTICAEAE

Boehmeria cylindrica (L.) Sw. Moist areas near ponds. Common. June-Sept.

Parietaria pennsylvanica Muhl. Well shaded areas in oak woods and shaded roadsides. Common. June-Sept.

VERBENACEAE

Phyla lanceolata (Michx.) Greene. Moist areas near ponds. Common. June-Sept.

Verbena hastata L. Moist areas near ponds. Occasional. July-Sept.

V. stricta Vent. Abandoned fields, roadsides, and other disturbed areas. Common. June-Sept.

V. urticifolia L. Roadsides and other disturbed areas. Occasional. July-Aug.

VIOLACEAE

Viola fimbriatula Smith. Moist areas near ponds, particularly in Polytrichum mats. Common. Apr.-May.

V. lanceolata L. Moist areas near ponds, particularly in Polytrichum mats. Common. Apr.-May.

V. papilionacea Pursh. Well shaded, moist areas in oak woods. Occasional. Apr.-May.

V. pedata L. Oak woods. Common. Apr.-May.

V. rafinesquii Greene. Abandoned fields and oak woods. Very common. Apr.-May.

VITACEAE

Parthenocissus quinquefolia (L.) Planch. Fencerows and oak woods. Very common. June-July.

Vitis aestivalis Michx. Well shaded, moist areas in oak woods. Occasional.

V. vulpina L. Abandoned fields, fencerows, and oak woods. Common. May.

XYRIDACEAE

Xyris torta Sm. Moist areas near ponds, particularly in Polytrichum mats. Occasional.

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PREVALENCE OF METACERCARIAE OF *CRASSIPHIALA BULBOGLOSSA* (TREMATODA, STRIGEOIDEA) IN FISHES OF THE HEADWATERS OF THE EMBARRAS RIVER, ILLINOIS

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ABSTRACT. Five of the twenty-three species of fishes collected from the Embarras River in Champaign Co., Illinois, were infected with metacercariae of the digenetic trematode *Crassiphiala bulboglossa*. Intensity of infection varied with respect to downstream location, species of hosts, specific body area of the host, and age of the host.

INTRODUCTION

Metacercariae of many digenetic trematodes encyst in the skin and flesh of various species of fishes where they are externally visible as small black spots. The metacercariae remain within the skin until the fish is eaten by a predatory bird, such as a kingfisher, which serves as the definitive host (Allison, 1950; Hoffman, 1956, 1967).

Examination of external cysts on infected fishes collected from the headwaters region of the Embarras River in Champaign Co., Illinois, revealed one species of digenetic trematode parasite identified as *Crassiphiala bulboglossa* Van Haitsma following Hoffman's (1967) synopsis. Dr. G. L. Hoffman (pers. comm.) confirmed the identification of this species from sketches of the parasite.

There have been no previous studies of fish parasites of the Embarras River. This paper describes the prevalence of *C. bulboglossa* on certain species of Embarras River headwater fishes, the prevalence of infection at various downstream locations, and the location of *C. bulboglossa* in specific body areas of the host. The relationship of parasite population density to fish host age will be discussed.

MATERIALS AND METHODS

Fishes were collected during October, 1973, with a small mesh minnow seine at stations along the Embarras River in Champaign Co.,

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designated by Menzel (1952) in his study of successional patterns of fishes. To evaluate parasite density shifts in time with regard to fish host age and infection of specific body areas, metacercarial counts from fishes collected at station 8 in 1971 and 1973 were compared. Approximately forty pigmented cysts were dissected from the integument and scales of specimens of each parasitized species found in the 1971 and 1973 collections. The metacercarial cysts were stained with borax carmine and, in some cases, counterstained with fast green, mounted, and microscopically examined.

For a comparison of the relative densities of parasites among specific body areas in the creek chub, Semotilus atromaculatus, the following conversion was used. The body surface was divided into the following areas: head, dorsal to lateral line, ventral to lateral line, dorsal fin, caudal fin, and ventral fins (anal, pelvics, and pectorals). The fins or sections of skin were dissected from the body and traced on paper which was analytically weighed. A specific body area ("ventral to lateral line") was chosen as a standard to which other areas were compared. The formula used to determine body area densities as compared to the ventral surface is as follows; Let N_{BA}= average number of cysts recorded for a specific body area, N_R= relative number of cysts with respect to the standard ventral surface area, W_{BA}= surface area "weight" for a specific body area, W_V= surface area "weight" for the ventral area. From $N_{BA}/W_{BA} = N_R/W_V$ comes $N_R = (W_{BA}/W_V)$. N_R is the relative density employed in this study.

Semotilus atromaculatus specimens from the 1971 and 1973 station 8 collections were divided into three total length classes as follows: 4.0-8.9 cm (small), 9.0-11.9 cm (medium), 12.0-16.0 cm (large). Parasite densities in the various length classes were computed by averaging the number of cysts from the total number of individuals of each class and weighting whis average relative to a standard total surface area (that of the medium sized fish).

Scientific names of fishes used in this study are those listed by Bailey et al. (1970).

RESULTS

Of the twenty-three species of fishes collected, only five species; Campostoma anomalum, Notropis spilopterus, Notropis stramineus, Pimephales notatus, and Semotilus atromaculatus, contained C. bulboglossa metacercarial cysts. The degree to which each of these species was infected is shown in Table I. The distribution of headwaters fishes usually follows a definite physiographic successional pattern (Shelford, 1911; Burton and Odum, 1945; Sheldon, 1968). This pattern in the Embarras River, with the notation of infected fishes, is illustrated in Table I. The prevalence of C. bulboglossa in the four major host species from each collecting station is shown in Figure I.

A comparison of S. atromaculatus specimens from the station 8 collections (1971 and 1973) shows similar relative parasite densities of designated body areas (Table 2). The body areas listed in increasing order as to their parasite densities are: dorsal fin, ventral fins, head, ventral surface, dorsal surface, and caudal fin. The 1971 and 1973 station 8 data also indicate parallel trends of increasing parasite density in relation to increasing host (S. atromaculatus) length (Figure 2).

DISCUSSION

C. anomalum, N. spilopterus, P. notatus, and S. atromaculatus were determined to be the "suitable fish hosts" (Allison, 1950) of Crassiphiala bulboglossa in the Embarras River headwaters. The single cyst located in one N. stramineus specimen was not considered to be significant. C. bulboglossa metacercarial cysts have been previously reported from S. atromaculatus (Hoffman, 1967; DuBois, 1970) and C. anomalum (Cloutman, 1976) but have not been reported from N. spilopterus, N. stramineus, or P. notatus. Crassiphiala bulboglossa cysts have been reported from several fish hosts including Esox americanus, Esox lucius, Notemigonus crysoleucas, Etheostoma nigrum, and Ericymba buccata (Hoffman, 1956, 1960; DuBois, 1970). These fishes were captured in the Embarras River headwaters but were not found to be parasitized by C. bulboglossa. The first four of the previously listed species were found in quantities too small to expect infection given the degree of parasitism of the other major fish hosts. However, E. buccata, a common cyprinid species in the Embarras River headwaters, remained free of C. bulboglossa cysts for unknown reasons.

An analysis of the geographic distribution of parasitized fishes must consider the distribution of other intermediate hosts which may in turn be influenced by environmental conditions. C. bulboglossa are known to pass through a snail intermediate host (genus Helisoma) which has been identified from the Embarras River headwaters as H. trivolvis (J. Suloway, pers. comm.). This snail species is known to prefer quiet, shallow, stagnant or semi-stagnated waters (Branson, 1961; Harman and Berg, 1971). The upper Embarras River should provide acceptable habitat for this species, however quantitative and local distributional data are lacking. Snails produce infectious cercariae which may then encyst in the fish host. Infection probably takes place in restricted areas as it is unlikely that cercariae swept downstream would be effective due to dilution effects and the short cercarial life expectancy. Thus, the distribution of the snail host may play a key role in determining which fishes become infected.

It appears that a successional pattern exists relative to C. bulboglossa infection with individual data for C. anomalum, P. notatus, and S. atromaculatus indicating an increase in degree of infection from station 1 to station 8 (Figure 1). These three species maintain relatively stable populations in this drainage in terms of relative abundance (Buth, 1974) possibly restricting their movements relative to the rather arbitrarily chosen collecting stations, although evidence for seasonal fluctuations in other P. notatus populations

have been reported (Smith, 1963). Thus, the apparent pattern of increasing degree of infection in these species may reflect some successively distributed parameter, possibly an increase in availability of infectious cercariae from the snail intermediate hosts. The infection of N. spilopterus did not exhibit a successionally oriented distribution (Figure 1) as previously described for the other host species. However, the population of this species varies seasonally (Buth, 1974) and the "mixing" of individuals during migration would effectively dilute any successional effects of parasitic infection.

Allison (1950) stated that the encysted metacercariae remain burrowed in the fish host until the fish is preyed upon by a bird or otherwise dies. This study supports that hypothesis by showing a steady increase in the relative densities of parasites as the fish size and age increases (Figure 2). Assuming the average rate of C. bulboglossa attack to be fairly constant and knowing that the fish surface area increases at a slower rate than the volume, the relative C. bulboglossa densities would increase with fish size.

Data for relative body area densities indicate agreement in infection patterns for the 1971 and 1973 S. atromaculatus collections (Table 2). The relative trematode density was found to be greatest for the caudal fin. The dorsal side was also highly parasitized and showed consistantly higher parasite densities than was found on the ventral surface. The relative parasite densities of the head and ventral fins tended to be similar and somewhat greater than the lowest density area, the dorsal fin. A general picture of the behavior of S. atromaculatus could prove valuable in a partial account for the densities observed. The frictional forces involved with substrate contact might explain reduced ventral surface densities as compared to higher dorsal surface densities. Possibly the acetabulum of the cercaria cannot remain fixed long enough to allow trematode encystment on the ventral surface.

Various factors affecting regional surface densities of C. bulboglossa deserve further study. Additional information concerning the local distribution, abundance, and degree of C. bulboglossa infection of the snail intermediate host may help to explain the patterns of infection observed in this study.

ACKNOWLEDGEMENTS

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Table 1. Distribution of fishes and prevalence of Crassiphiala bulboglossa infection in the Embarras River headwaters. Numbers of infected fishes are indicated in parentheses.

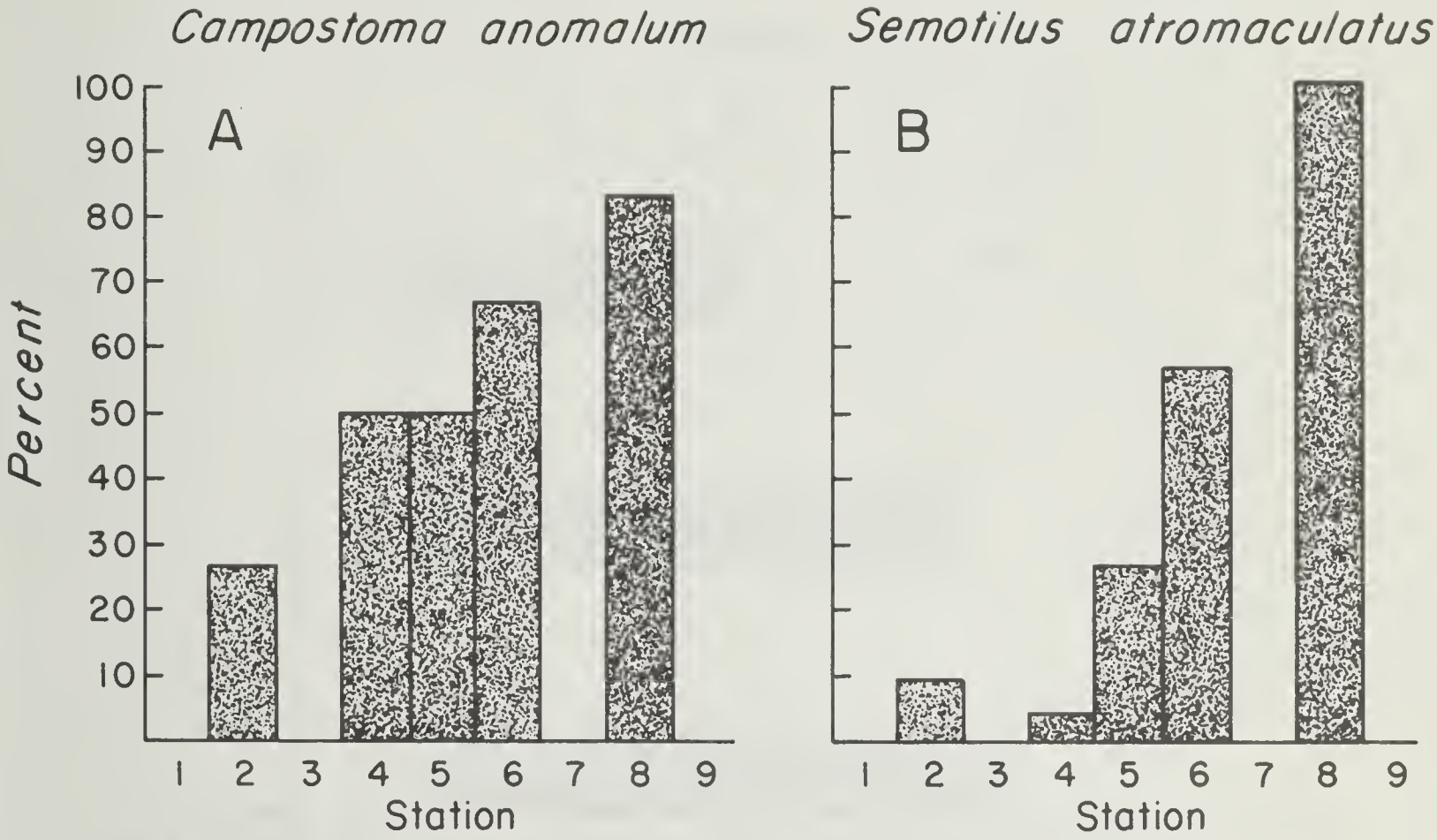
	SPECIES	STATIONS									TOTAL	PERCENTAGE PARASITIZED
		1	2	3	4	5	6	7	8	9		
1.	Pimephales notatus*	10	127(11)	10(2)	15(2)	13(2)	13(4)	2	64(40)	19(1)	273(62)	22.7%
2.	Lepomis cyanellus	2	7	6	4	8	9	5	1		42	0
3.	Notropis spilopterus*	1	24(8)	2(1)	2(1)	2(1)	4(2)		7(2)	1	43(15)	34.9
4.	Lepomis megalotis		15	4	1	18	2	5	6	7	58	0
5.	Notropis stramineus*		21	3	16(1)	7	3		33		83(1)	1.2
6.	Notropis umbratilis		21	1				33	13		68	0
7.	Campostoma anomalum*		15(4)		12(6)	2(1)	3(2)		12(10)		44(23)	52.2
8.	Semotilus atromaculatus*		75(6)		22(1)	18(4)	7(4)		43(43)		165(58)	35.2
9.	Fundulus notatus		3		3	8	5			5	24	0
10.	Lepomis humilis		35		2	2		4			43	0
11.	Ericymba buccata		8			21	6		73		108	0
12.	Erimyzon oblongus		3			2		6			11	0
13.	Lepomis macrochirus		20					2			22	0
14.	Ictalurus natalis		2					1			3	0
15.	Phenacobius mirabilis					3			3		6	0
16.	Aphredoderus sayanus					1					1	0
17.	Catostomus commersoni							5	3		8	0
18.	Esox lucius							1			1	0
19.	Notemigonus crysoleucas							6			6	0
20.	Ictalurus melas							1			1	0
21.	Etheostoma nigrum							1			1	0
22.	Pomoxis annularis							1			1	0
23.	Esox americanus								1		1	0
Total number of species		3	14	6	9	13	9	14	12	4	23	
Total number of specimens		13	376	26	77	105	52	73	259	32	1013(159)	15.7

*Species found to carry C. bulboglossa metacercariae.

Table 2. Average relative densities of parasites on various body areas of Semotilus atromaculatus collected at station 8 in 1971 and 1973 (the absolute average number of parasites per body region as corrected relative to the standard ventral surface area).

	Small		Medium		Large	
	1971	1973	1971	1973	1971	1973
Dorsal Fin	2.8	0	8.2	3.8	30.9	17.0
Ventral Fins	1.7	2.2	11.0	6.8	36.9	21.8
Head	2.5	2.0	12.5	6.5	37.3	19.0
Ventral Surface	4.3	2.3	16.2	7.5	34.9	25.9
Dorsal Surface	5.7	2.5	25.8	9.0	52.1	29.2
Caudal Fin	4.4	3.8	25.5	10.2	62.6	31.9
Total Fins	2.6	2.4	15.1	7.4	43.9	24.1

Figure 1. Percentage of parasitized individuals of: (A) C. anomalum, (B) S. atromaculatus, (C) N. spilopterus, and (D) P. notatus, at various collecting stations in the headwaters of the Embarras River.


Campostoma anomalum
A
Semotilus atromaculatus
B
Percent
100
90
80
70
60
50
40
30
20
10
1 2 3 4 5 6 7 8 9
Station

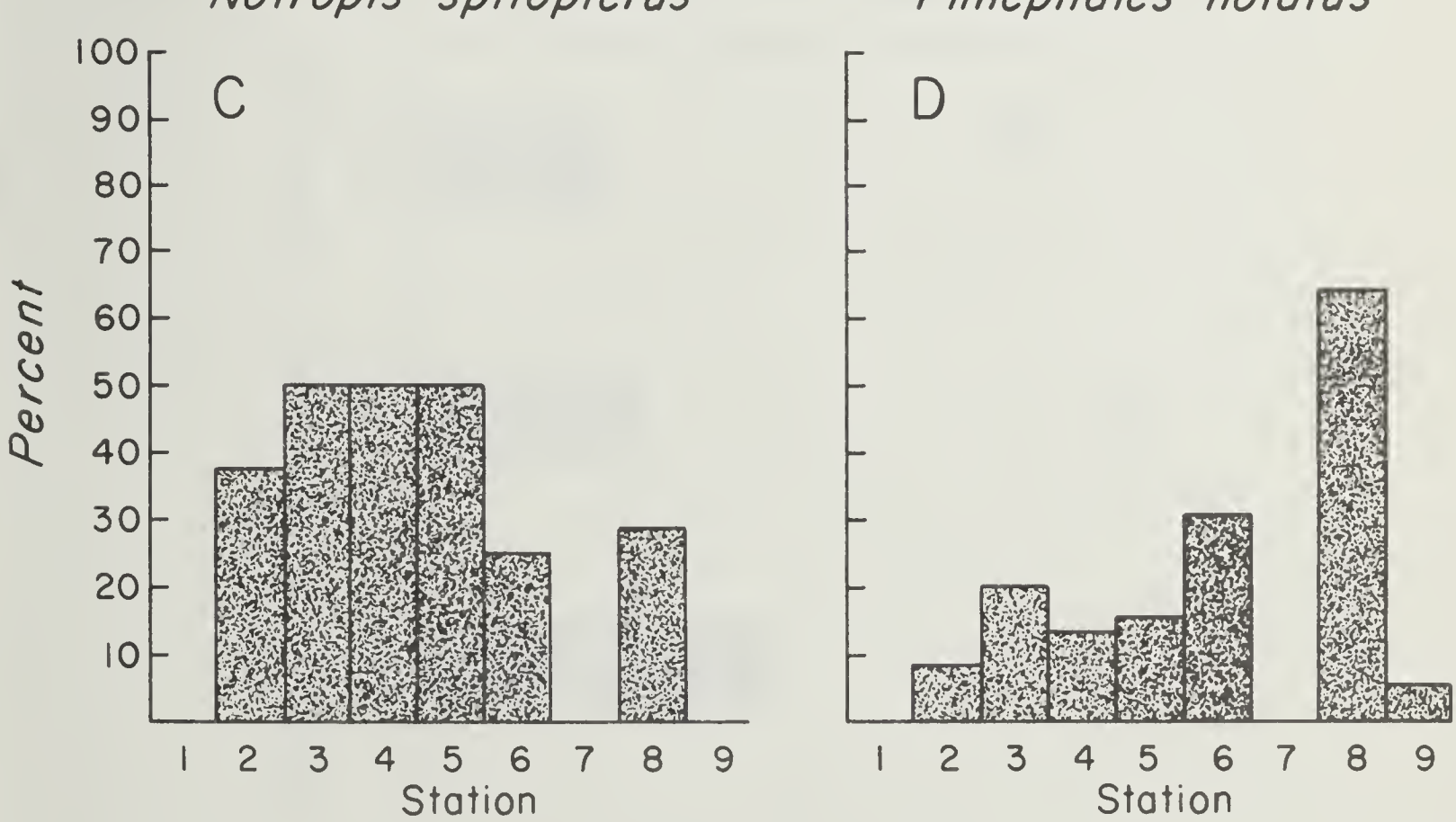
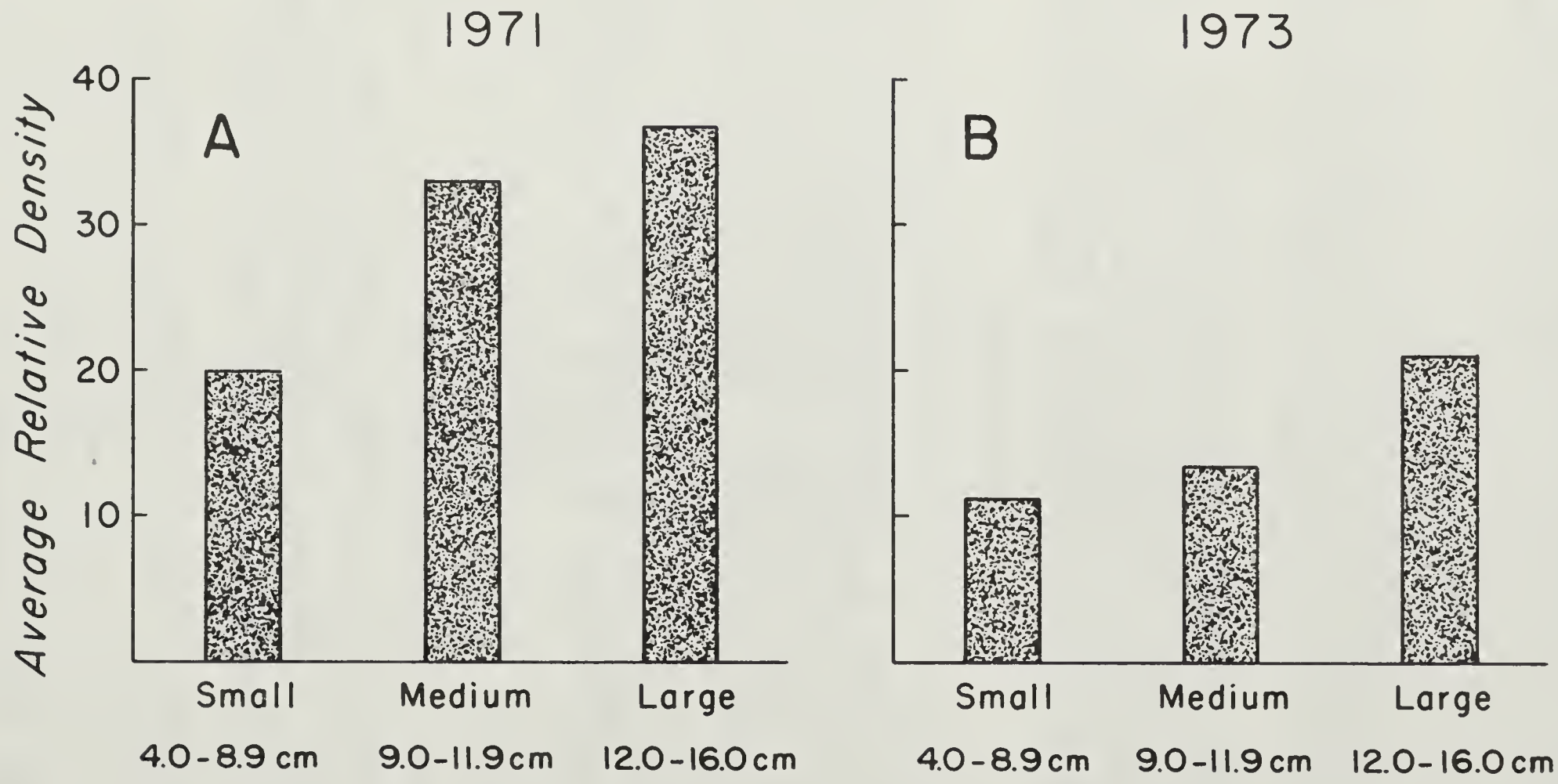

Notropis spilopterus
C
Pimephales notatus
D
Percent
100
90
80
70
60
50
40
30
20
10
1 2 3 4 5 6 7 8 9
Station

Figure 2. Average relative densities of parasites on three length classes of Semotilus atromaculatus collected at station 8 in (A) 1971 and (B) 1973 (the absolute average number of parasites per fish size as corrected relative to the standard medium sized fish).


1971
1973
A
B
Average Relative Density
40
30
20
10
Small
4.0-8.9 cm
Medium
9.0-11.9cm
Large
12.0-16.0cm
Small
4.0-8.9cm
Medium
9.0-11.9 cm
Large
12.0-16.0 cm

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FOX SQUIRREL UTILIZATION OF CATKINS AND ACORNS OF THE BLACK OAK GROUP

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ABSTRACT

The feeding of fox squirrels (Sciurus niger) on catkins of oak (Quercus spp.) is described. Black oak (Q.velutina) and southern red oak (Q. falcata) received the highest utilization. Observation suggests that the catkins of the black oak group may be a significant spring food source for the fox squirrel. Also, evidence indicates that there should be delineation between oak groups due to their relative contributions toward the survival of fox squirrels.

INTRODUCTION

Baumgartner (1938), working with the fox squirrel (Sciurus niger) in Ohio, described the acorns of oak (Quercus spp.) as a year-round "staple" food, and the pistillate catkins of willow (Salix spp.) as an "emergency" food source. Havera, Nixon and Collins (1976) report the feeding of fox squirrels on buckeye (Aesculus glabra) pith.

Information gathered in southern Illinois indicates that acorns of the black oak group are the only acorns available on a year-round basis, and that their catkins may be an important spring food source for the fox squirrel.

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RESULTS AND DISCUSSION

On the afternoon of March 25, 1976, heavy use of oak catkins was noted by Harty when five fox squirrels were observed feeding atop a large southern red oak (Q. falcata) at Thompson Woods on the campus of Southern Illinois University at Carbondale. This activity was reminiscent of the concentrated fall feeding of squirrels in hickory (Carya spp.) trees.

Examination of twigs cut by squirrels revealed a feeding solely on oak catkins. Closer scrutiny disclosed that only a small portion of the many catkins available on each twig was actually eaten. Many individuals were observed to take only a single mouthful of catkins before dropping the twig and cutting another.

A similar observation was noted by Nichols (1927) while watching gray squirrels (Sciurus carolinensis) on Long Island, New York. Nichols reported gray squirrels feeding on the catkins of scarlet oak (Q. coccinea) on April 27-29 and on the catkins of white oak (Q. alba) on May 24-29. Their feeding was described as lavish and wasteful.

The feeding technique utilized by fox squirrels was similar to their nut-eating posture. After cutting a twig, they would right themselves into a sitting position in the crown of the tree with their front paws free to handle the twig. Many twigs were dropped due to this precarious position. However, there was never a display of angry chatter when a twig was prematurely dropped as is often observed in the fall after the loss of a nut or acorn.

On the afternoon of April 9, three fox squirrels were observed feeding together in the top of a mature black oak (Q. velutina) in Thompson Woods. These individuals were watched until they quit feeding at sunset. The next morning, cuttings under the tree were collected and counted. In one feeding session these three squirrels cut 136 catkin laden twigs, averaging 45 twigs per squirrel.

On April 10, the same black oak was watched to check the figures from the previous day. That afternoon only two squirrels appeared to feed in the oak and cut 84 twigs in that feeding session, averaging 42 twigs per squirrel. Feeding sessions on both days began at approximately 4:00 PM and ended with sunset at 6:45 PM.

Collectively, these five squirrels cut 220 twigs in two feeding sessions from a single black oak. Many twigs that were cut and dropped were intercepted by lower branches and midcanopy species. Thus, these figures represent an underestimate of total feeding, as about one of every three

cuttings were intercepted and unretrievable.

Twigs were dropped prematurely and an overall increase of wastefulness occurred when there were two or more squirrels feeding in the same tree. A lone squirrel observed feeding in the crown of an isolated black oak exhibited a more deliberate feeding technique and cut 36 twigs during one feeding session.

Although there were scattered individuals of white oak (Q. alba), post oak (Q. stellata), and northern red oak (Q. rubra) in Thompson Woods, fox squirrels were not observed to feed on their catkins. However, an individual was observed feeding on the catkins of a pin oak (Q. palustris) planted at the edge of the woods.

Other spring foods, taken by the fox squirrels in Thompson Woods, included the samaras of American elm (Ulmus americana), winged elm (U. alata), silver maple (Acer saccharinum), and the acorns of black oak (Q. velutina) and pin oak (Q. palustris).

Brown and Yeager (1945) consider stands composed primarily if black oak (Q. velutina) to be inferior squirrel habitat. Thompson Woods is an 18-acre woodlot dominated by black oak (70%) and has an estimated fox squirrel population of 2.3-3.6 squirrels per acre (Eveland 1974).

Investigators working with white-tailed deer (Odocoileus virginianus) in Missouri, found that white oak (Q. alba) acorns were of little use to deer since they exhibit no embryonic dormancy, and either germinate or rot soon after falling from the tree (Hosley 1956). In relation to the fox squirrel, this information is also valid.

With the exception of bur oak (Q. macrocarpa), all the members of the white oak group found in Illinois lack embryo dormancy. In contrast, members of the black oak group do exhibit embryo dormancy, and do not germinate until spring (Olson 1974). Thus, the acorns of the black oak group are an available food source for fox squirrels through fall and into spring, whereas, acorns of the white oak group are only available in the fall.

SUMMARY AND CONCLUSIONS

The intensive utilization of oak catkins by the squirrels observed, indicates that oak catkins may be an underestimated spring food source of the fox squirrel, especially the early flowering forms such as Quercus falcata and Quercus velutina. Also, due to the overall contribution of the black oak group to the survival of the fox squirrel, members of the black oak group should be favored over the white oak group in the management of woodlots for fox squirrel habitat.

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THE ENICOCEPHALIDAE (HEMIPTERA) IN ILLINOIS

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ABSTRACT

Systelloderes biceps is the only species of Enicocephalidae (Hemiptera) collected in Illinois. Notes on *S. biceps* mating swarms and distribution are presented.

The Enicocephalidae, or gnat bugs, are small predaceous Hemiptera. In Illinois, there is one species, *Systelloderes biceps* (fig. 1), which is about 3 mm long. They have a brown head and thorax with a light abdomen and membranous wings. The adults can be macropterous or micropterous. Micropterous forms of *S. biceps* have been described under other names.

S. biceps have been collected from early April to late November in decaying logs, leaf litter, and in mating swarms. They have also been attracted to black light traps.

The enicocephalid mating swarm is formed over a marker or station. The swarm consists predominately of males and resembles a chironomid mating swarm (Schuh 1970). Four such swarms have been collected in Illinois, two from Champaign, and two from Urbana. The largest swarm collected was taken by Dr. H. B. Mills in August 1950 in Champaign; it consisted of 303 males and 7 females.

The known record of *S. biceps* in Illinois is shown in figure 2. The LaSalle County collection may be the most northern Illinois distribution because they have not been collected in Wisconsin.

Illinois records include Piatt Co.: Nette Hart Mem. Woods, Mahomet, 6-8-1966 to 11-24-1966, 3 macropterous males and 5 macropterous females, M.W. Sanderson, blacklight; Monticello, 6-12-1958, 1 macropterous male, M.D. Farrar; Allerton Park, 5-17-1967, 2 nymphs, L.J. Stannard, woodland debris; Allerton Park, 6-14-1973, 1 macropterous female, J.D. Unzicker, blacklight; White Heath, 10-29-1939, 1 nymph, J.C. Dirks, soil; Champaign Co.: Urbana, 4-27-1945, 7 nymphs, H.H. Ross and L.J. Stannard, under log; Urbana, 9-17-1950, 8 macropterous males, S. Sanderson, sweeping grass; Trelease Woods near Urbana, 5-25-1951, 1 macropterous male, R.K. Benjamin, leaf mold; University of Illinois Ecological Research Area near Urbana, 6-6-1971 to 7-17-1971, 14 macropterous males and 1 macropterous female, P.W. Price, pan traps; University of Illinois Ecological Research Area

near Urbana, 6-4-1972 to 7-19-1972, 42 macropterous males and 7 macropterous females, P.W. Price, pan traps; Champaign, 8-10-1949, 5 macropterous males, H.H. Ross and L.J. Stannard, flying at dusk; Champaign, 8-16-1949, 19 macropterous males and 2 macropterous females, H.B. Mills, swarming at dusk; Champaign, 8-10-1957, 1 macropterous female, J. Kingsolver, landed on arm; Champaign, August 1950, 303 macropterous males and 7 macropterous females, H.B. mills, swarming at dusk; Mayview, 9-18-1939, 1 nymph, M.D. Farrar, bunchgrass sod; 2 miles north of Homer over Salt Fork, 9-28-1973, 1 macropterous female, J.D. Unzicker, blacklight. LaSalle Co.: Starved Rock State Park, 5-6-1944, 1 nymph, M.W. Sanderson. Clay Co.: Bible Grove, 4-10-1947, 1 nymph, B.Burks. Adams Co.: Quincy, 5-22-1943, 2 micropterous females, C. Hoff, leaf litter. Vermilion Co.: Muncie, September 1953, 5 nymphs, Ross and Somerman, under bark. Union Co.: Union Co. Wildlife Refuge near Ware, 10-24-1957, 5 nymphs, M.W. Sanderson. Perry Co.: Du Quion, 9-24-1948, 3 nymphs, H.H. Ross and L.J. Stannard. McLean Co.: Funks Grove near Bloomington, 9-2-1962, 1 macropterous male. Mason Co.: San Ridge State Forest, 9-14-1975, 12 nymphs, G.R. Kritsky, under bark. Fayette Co.: Brownstown, 8-8-1960, 1 nymph and 1 micropterous female, G.T. Riegel, sawdust pile. Moultrie Co.: Lake Shelbyville, 6-3-1975, 1 macropterous male, D. Webb, blacklight.

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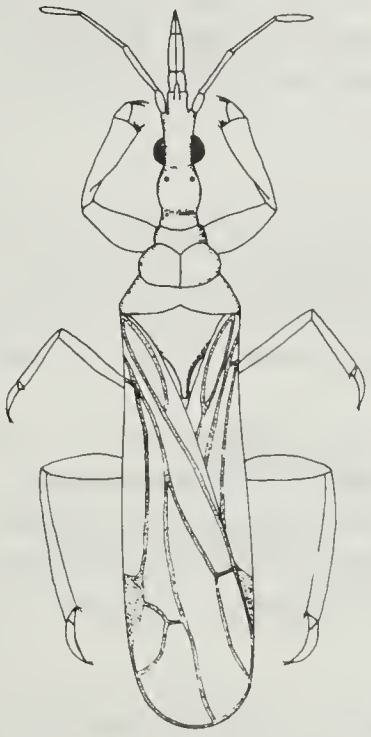

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Fig. 1 - Systelloderes biceps, male.

Fig. 2 - Illinois distribution of S. biceps.

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FLOWERING PLANTS NEW TO ILLINOIS

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ABSTRACT

The species Hydrocotyle ranunculoides L.f., Oenothera triloba Nutt., and Sedum rupestre L., and the forms Symphoricarpos orbiculatus Moench f. leucocarpus (D.M. Andrews) Rehder, and Aquilegia canadensis L.f. flaviflora (Tenney) Britt. are reported from Illinois for the first time.

In this paper three species and two forms of vascular plants are reported for the first time from Illinois. These additions to the flora are the result of extensive field work by the authors during the past 4 years. All specimens are deposited in the Stover Herbarium of Eastern Illinois University (EIU).

Hydrocotyle ranunculoides L.f. This water-pennywort grows in great abundance in a cat-tail marsh about 1 mile west of Centralia, Clinton County, Illinois (SW¼, NE¼, Sect. 10, T1N, R1W). This probably represents the most northern station for this species in central United States as Fernald (1950) gives its range as north to Arkansas and Oklahoma. It was collected by R. Nyboer (#290) on October 3, 1975.

Oenothera triloba Nutt. Several plants of this species were found at the edge of a cultivated field ¼ mile from Rattlesnake Ferry, Jackson County, Illinois (SE¼, Sect. 22, T10N, R3W). This small population was growing in light, sandy soil about 200 yards from the Big Muddy River. Deam (1940) reported this species from a few counties in extreme southeastern Indiana, while Steyemark (1963) lists it as scattered and rare in the Ozark region of Missouri. Its occurence in southern Illinois, therefore, is not unusual. The Illinois material was collected by J. Reeves (s.n.) on May 7, 1972.

Sedum rupestre L. This commonly cultivated stonecrop is a native of Europe that may be found in gardens throughout Illinois. This species is reported as naturalized in a few eastern states by Fernald (1950) and now Illinois should be added to the list. A few individuals were found growing in a limestone hill prairie on thin loess. The locality is in St. Clair County, Illinois near Sugar Loaf Heights (NW¼, NE¼, Sect. 33, T1N, R10W). The seed source was probably a rock garden in the front yard of a house about 100 yards away. The specimen was collected by R. Nyboer (#455) on June 25, 1976.

Aquilegia canadensis L.f. flaviflora (Tenney) Britt. This form of columbine with flowers that are entirely yellow to pale yellow was found in an upland woods at the edge of a road about 1½ miles west of New Athens, St. Clair County, Illinois (NE¼, SE¼, Sect. 30, T2S, R7W). The population consisted of a few individuals with yellow flowers and a large number of the normal flower-colored individuals (f. canadensis). Steyermark (1963) reported two stations of this form from Missouri. Both were on wooded ravine slopes with limestone outcrops. The Illinois material was collected by R. Nyboer (#454) on May 20, 1976.

Symphoricarpos orbiculatus Moench f. leucocarpus (D.M. Andrews) Rehder. This form of coralberry with yellowish to whitish colored fruits was found at the edge of a cultivated field 8 miles northeast of Charleston, Coles County, Illinois (SE¼, Sect. 15, T13N, R10E). The population consisted of five individual plants with numerous individuals of the red fruited form (f. orbiculatus). Deam (1940) reported one station of this white fruited form from Indiana. The Illinois material was collected by J. Ebinger (#15582) on January 12, 1976.

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THE EMERGENCE OF THE PERIODICAL CICADA (BROOD XXIII) IN ILLINOIS IN 1976 (HOMOPTERA: CICADIDAE)

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ABSTRACT

The distribution of the 1976 emergence of Marlatt's brood XXIII in Illinois is presented. The history of this brood is examined and explanations of its present distribution are discussed.

In 1976 Illinois witnessed the emergence of the lower Mississippi Valley Brood of the periodical cicada or Marlatt's XXIII. The emergence occurred in three discrete areas of the state as seen in figure 1. Records were obtained from May 21 in Williamson Co. to June 19 in Dewitt Co. County records include one to several collections from Pulaski Co., Alexander Co., Union Co., Johnson Co., Williamson Co., Jackson Co., Randolph Co., Washington Co., Wabash Co., Lawrence Co., Crawford Co., Champaign Co., Piatt Co., and Dewitt Co. Stray cicadas were reported from Pope Co., and Harden Co.

Brood XXIII was first recorded in Illinois in 1859 by Cyrus Thomas (1865), and a major effort to map its distribution was made by Stephen A. Forbes, Director of the State Laboratory of Natural History, in 1898. In that year Forbes confirmed the cicadas' occurrence in 22 counties and added five new county records (Marlatt 1907). The distribution of brood XXIII in 1898 is shown in figure 2. This brood was not mapped again until 1963 by Dr. Lewis Stannard, but its distribution was questionable due to the simultaneous emergence of brood III (Stannard 1975).

If one assumes that Forbes' map is correct, then one sees that the disjunct distribution between the two southern areas of emergence is a result of the disappearance of brood XXIII from part of the state. Such declines in the cicadas' distribution have been discussed by Young (1958).

The origin of the Dewitt-Piatt and Champaign Co. emergence zone is unknown. It is possible that Forbes did not obtain records from these counties, but one must note that Forbes lived 12 miles from the emergence zone and probably would have known about the area. Perhaps another brood that occurred in the area shifted its cycle and now emerges with brood XXIII. But evidence for such shifts is questionable (Young 1958).

Another explanation is that the cicadas invaded the area. Cicadas are very adaptable and they have invaded suburban gardens, hedges, and even new trees in spoil heaps in strip mines (Dybas and Lloyd 1974). But the distance to the nearest population of brood XXIII is over 90 km, making invasions difficult.

ACKNOWLEDGEMENTS

We would like to thank Dr. Lewis J. Stannard for his help and commentary. We also wish to thank Y. Kritsky, C. Gerdes, J. Mari Mutt, L. Crain, D. Webb, R. Graber, J. Graber, and the Prairie Entomological Society for obtaining collection localities, and B. Sweeney for helping prepare the manuscript.

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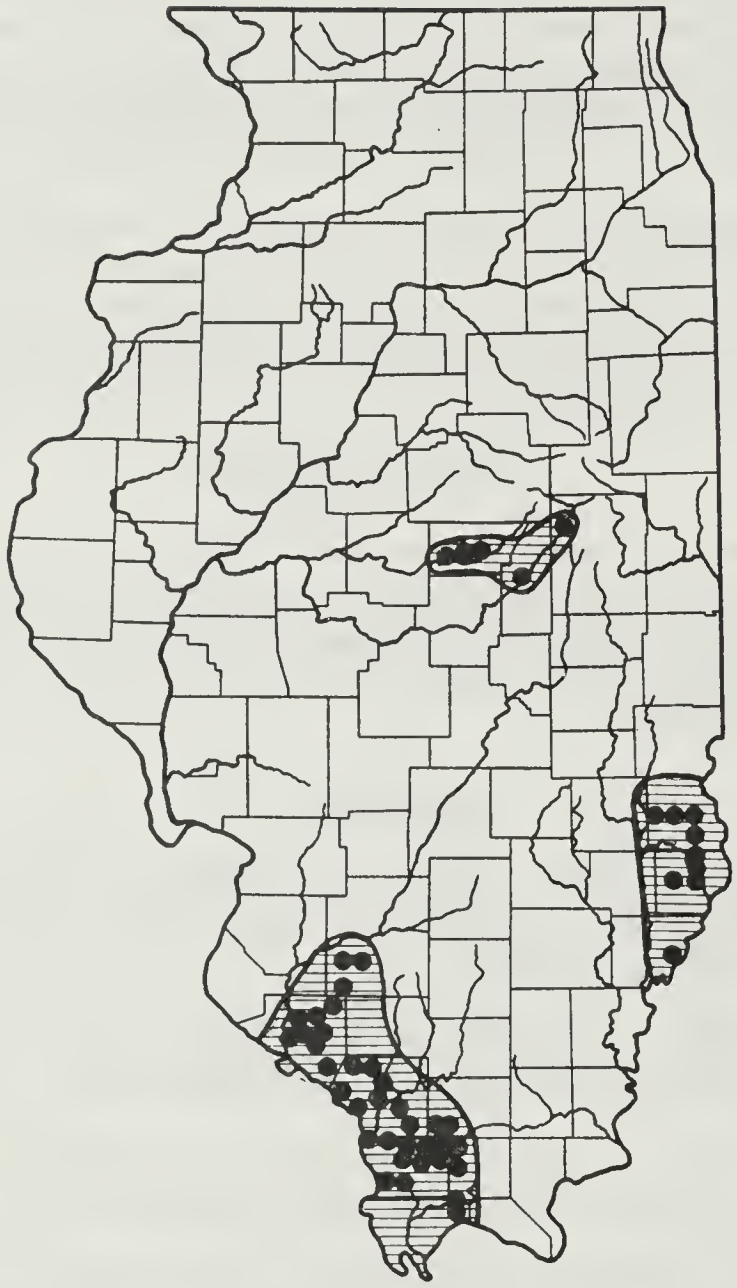

Figure 1 - 1976 distribution of brood XXIII

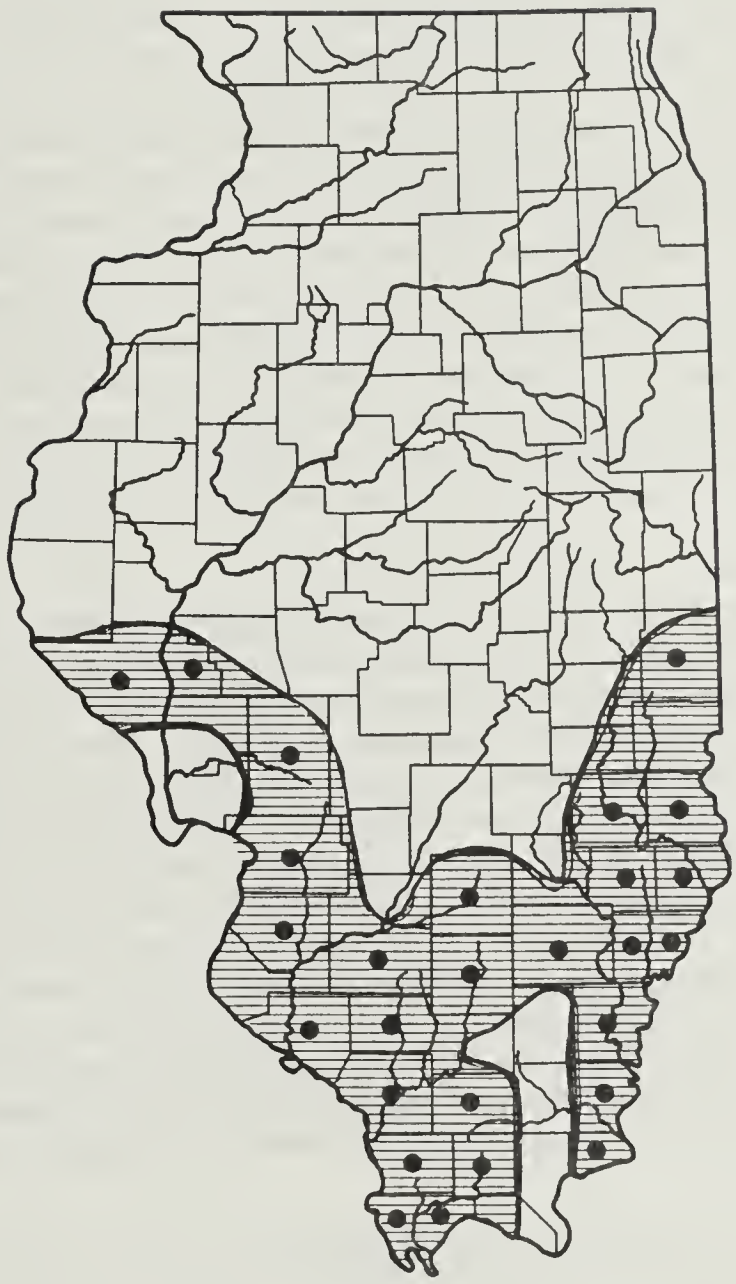

Figure 2 - 1898 distribution of brood XXIII

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HEAT PRODUCTION BY THE EASTERN BOX TURTLE (TERRAPENE CAROLINA CAROLINA) AS MEASURED BY DIRECT CALORIMETRY.[1]

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ABSTRACT. - Heat production by eastern box turtles (Terrapene carolina carolina) has been measured directly. The diet was a mixture of animal and plant foods with vitamins and bone meal. The calorimeter was a four liter Dewar flask kept in an insulated box at 24° ± 1°C. After a fast of three days each of ten animals was studied by hourly thermometer readings for a twelve hour period. The mean heat production was steady (linear) at 0.12 cal $h^{-1}g^{-1}$ for fasting animals resting in the dark at 24°C ± 1°C.

The purpose of this study has been twofold. First, the production of heat by the eastern box turtle has been observed under controlled conditions to test the reliability of the direct calorimetric methods. Second, inasmuch as this method appears to have been little used, if at all, then a comparison between the records obtained from the direct method with those reported by others who have made use of indirect calorimetry is an appropriate goal. Animals whose oxygen consumption or carbon dioxide production have been used to calculate heat production include: lizards (Martin, 1903); frogs (Krogh, 1914); alligators, large snakes, rattlesnakes, land tortoises (Benedict, 1932); painted turtles (Baldwin, 1926); red-eared turtles (Hutton et al, 1960); and Galapagos turtles (Dawes and Mestyan, 1963). Kaplan (1974) has summarized this literature. In other words, if one assumes that O_2 and CO_2 measurements can be used as indices of heat production in laboratory animals, and if these results agree with data directly obtained by the use of thermometers, then a simple method for direct calorimetry has utility.

MATERIALS AND METHODS

Animals. Ten eastern box turtles (Terrapene carolina carolina) were collected from their natural woodland habitats in eastern and southern Illinois. The species and sex were ascertained by the key given in Smith (1961). Their mean weight was 437 g (range 245 to 565 g) and the mean

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[1]This study was reported at the 69th annual meeting of the Illinois State Academy of Science, Knox College, Galesburg, Illinois 61401, on April 23, 1976.

[2]Please address correspondence about this report to R. E. Johnson, Biology Department, Knox College, Galesburg, Illinois 61401.

carapace length was 126 mm (range 111 to 138 mm). (See Rothschild, 1915).

The animals were housed in environmentally controlled rooms for four months before this study was started. Throughout the investigation lights, coming from 3-40 watt GE cool white fluorescent bulbs, were on from 6 AM to 6 PM local time. The temperatures were 27°C by day and 22°C by night. Dr. J. Wallach, Brookfield Zoo, has reported 27°C as being within a suitable range for laboratory adaptation by turtles. Sturbaum and Riedesel (1974) agree. The turtles in the present study have lived for eighteen months in our laboratory without a single death; each has gained weight. Health was maintained by the use of uncooked base diet consisting of two parts freshly ground beef, one part ground beef liver, and one part beef bone meal, beef fat, and beef bone marrow. This was supplemented with cod liver oil and a pediatric vitamin formula. The turtles were kept in pairs matched by size. The vitamin weekly supplement for each pair of turtles provided: iron 10 mg, A 0.45 mg, D_2 10 mcg, C 30 mg, B_1 0.4 mg, B_2 0.6 mg, B_6 0.4 mg, and niacinamide 6 mg. Fresh water was available at all times. In addition, sun lamp treatment, exercise routines and cage -animal cleanliness were maintained each week. Each pair was offered 50 g of meat diet each Monday and green vegetables with fruit each Thursday. The animals were housed in polycarbonate tubs with medium page bark (Far West Forests, Sacramento, California) as a substrate. Each animal had no food for three days before the initiation of this study.

Materials. The calorimeter consisted of a four liter Pope Dewar flask with an insulated top. A wet bulb thermometer, accurate to one-tenth degree C, was inserted through the calorimeter top. To allow for pressure equalization within the calorimeter, two catheters were also inserted through the insulated top and placed down inside the Dewar flask. Two additional thermometers were used to measure the ambient temperature and were positioned next to and at equal distances from the calorimeter. The calorimeter was placed inside an insulated box; the whole system (calorimeter, insulated box, and thermometers), was housed in another environmentally controlled room kept at 24°C $\pm$ 1. Prior to use, all thermometers were standardized with reference to one selected thermometer, namely the one inserted through the calorimeter top. The whole system was further insulated from air currents by placement under a hood consisting of polystyrene panels covered with insulating blankets.

Methods. Calibration of the calorimeter was done by using both hot (28°C) and cold (17°C) water. An amount of water equal to the weight of a corresponding turtle was placed inside the calorimeter. Temperature readings were taken every hour for twelve hours from all three thermometers. In this manner the thermal properties and heat flow into or out of the calorimeter were determined, permitting the calculation of a temperature gradient defined as follows: (calorimeter temperature - mean ambient temperature). Prior to actual experimentation all of the materials were allowed to equilibrate in the environmentally controlled room for a twelve hour period. During the experimental phase a turtle was placed inside the calorimeter along with twenty milliliters of deionized water. The heat production of the turtle was measured directly by readings taken from the one reference thermometer. Temperature readings were made every hour for a twelve hour period. The first two hours of experimentation were discarded in order to allow the turtles to adjust to the calorimeter.

Statistical Considerations. The generalized equation for heat balance, as stated in 1945 by Brody, has been used:

(Heat Stored) = (Metabolic Heat) - (Evaporative Heat) ± (Conduction) ± (Radiation) ± (Convection) ± (Heat Equivalent of Work) Eq. 1

By experimental design the last five variables in Eq. 1 become zero. The heat equation therefore became:

(Heat Stored) = (Metabolic Heat) Eq. 2

RESULTS

The mean heat production of these turtles (Terrapene carolina carolina) fasting, at rest, and in the dark at 24°C, was 0.12 cal $h^{-1}g^{-1}$, with a standard deviation of ± 0.05 cal $h^{-1}g^{-1}$ (Table 1). In international SI units these numbers are 0.52 J $h^{-1}g^{-1}$ ± 0.20 J $h^{-1}g^{-1}$, or 0.14mWg^{-1} ± 0.06 mWg^{-1}.)

TABLE 1. Heat Production of the Eastern Box Turtle (Terrapene carolina carolina) at 24°C Measured by Direct Calorimetry.

Sex	Body Weight grams	Heat Production cal $h^{-1}g^{-1}$	J $h^{-1}g^{-1}$
F	245	0.11	0.46
F	401	0.14	0.59
M	356	0.12	0.50
F	503	0.16	0.67
F	459	0.07	0.29
M	421	0.25	1.05
F	453	0.06	0.25
F	488	0.10	0.42
F	476	0.08	0.33
F	565	0.15	0.63
Mean	437	0.12	0.52
Standard Deviation	84	0.05	0.22

One important feature of the heat production was the consistency and regularity of the curves during the last 10 hours of each experiment (Figure 1).

The larger animals should produce heat faster than the smaller.

An x-y plot of slope m against body weight (Figure 2) showed a correlation ($r = -0.27$) between weight and slope. This justifies expressing heat production on a gram basis. There was no sex-related difference.

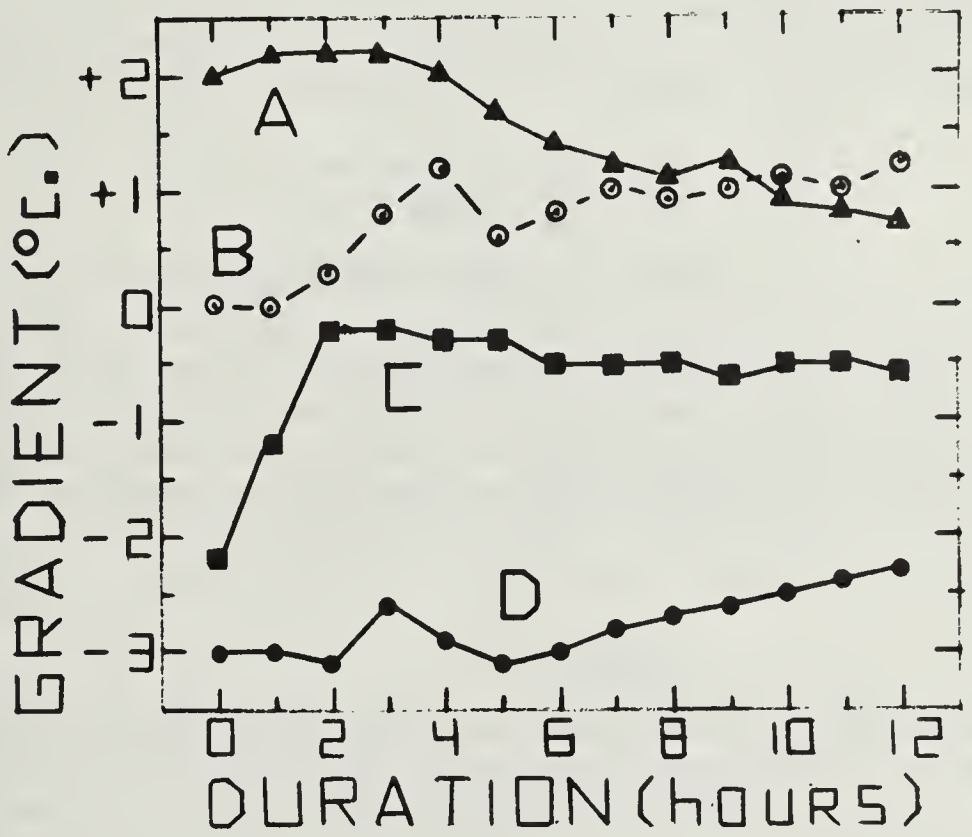

FIGURE 1. Changes in temperature gradients (inside to outside the Dewar flask) over 12 hours, with warm water at 28°C (A), water at room temperature 23°C (C), cool water at 17°C (D), and a female eastern box turtle (Terrapene carolina carolina) weighing 245 g, Code 1 (B).

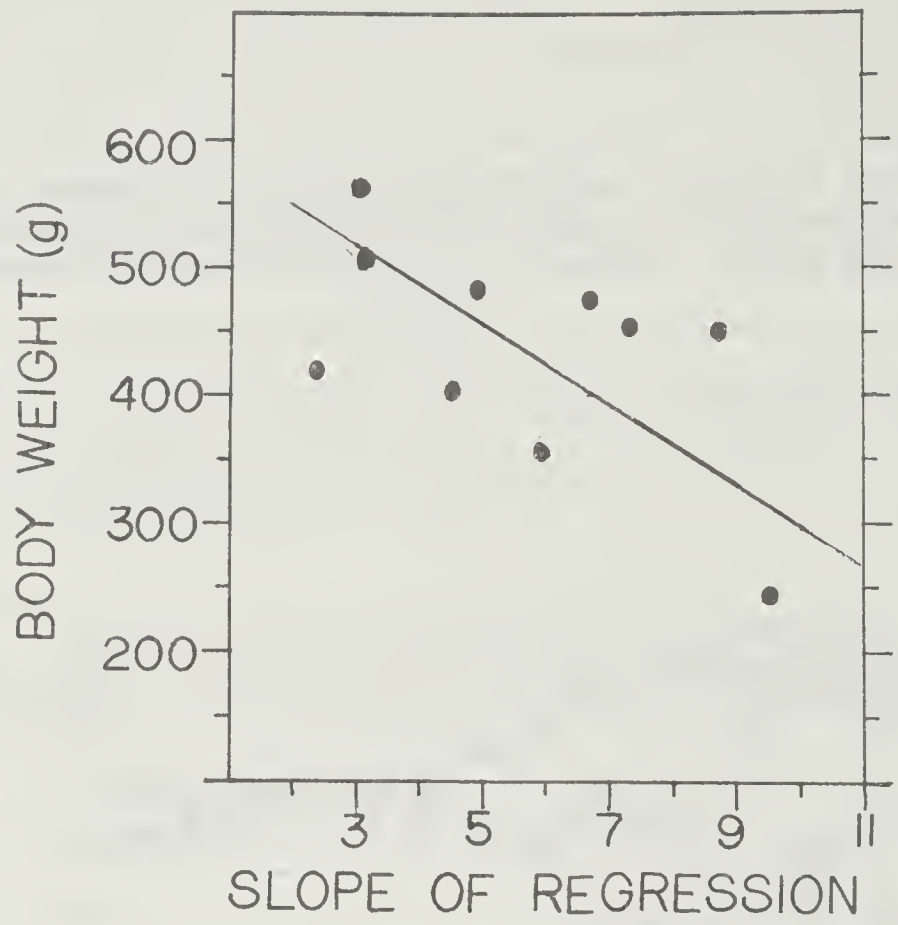

FIGURE 2. Body weight and slope of the regression equation for rise in temperature due to metabolic heat in eastern box turtles (Terrapene carolina carolina). The regression equation Y = -20X + 549 was fitted by the method of least squares (Moroney, 1965). The correlation coefficient was -0.27.

DISCUSSION

We have found no reports of direct measurement of the energy metabolism of the eastern box turtle (Terrapene carolina carolina) or for that matter any other chelonian. Workers (even Rubner, 1924) say "heat production" when all they have measured is oxygen consumption, carbon dioxide production, total weight loss, or some combination of these. This could be an important error if cold blooded animals produced a significant proportion of their heat through anaerobic pathways, and not exclusively aerobic. Our data do not bear on this point, and some authors who have studied heat regulation in turtles have not mentioned this possibility (Templeton, 1960; Sturbaum and Riedesel, 1974; Morgareidge and Hammel, 1975).

Among the data for chelonians, Benedict (1932) reported the results of indirect calorimetry on two species of large turtles, the giant Galapagos tortoise (Testudo vicina) and the South American gopher tortoise (Testudo denticulata). For three of the former he gave values ranging from about 1.2 to 4.2 kcal per kilogram total weight for 24 hours, and for five of the latter, values ranging from 1.3 to 9.7. Expressed in terms of gram calories per gram and hour, these become 0.05 to 0.18 for the former, and 0.05 to 0.11 for the latter. Our total range was 0.06

to 0.25 for 10 eastern box turtles (Terrapene carolina carolina). Benedict (1932) stated that he had tried, but failed, to measure heat production directly, and therefore used indirect calorimetry, calculating from the CO_2 production.

We believe that this is the first report of the use of direct calorimetry in chelonians. Our values are of the same order of magnitude as those reported by other workers using indirect calorimetry.

ACKNOWLEDGMENTS

We thank Dr. P. W. Smith, Illinois Natural History Survey, Urbana, Illinois, for his identification of our animals, and his general help with our problems.

We have received much assistance from Miss Patricia Berg, Knox College, for help with the manuscript, and also in the care of the animals. The work was supported by the Biology Department, Knox College, Galesburg, Illinois.

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ABSTRACTS OF PAPERS PRESENTED AT THE 69TH ANNUAL MEETING OF THE ILLINOIS STATE ACADEMY OF SCIENCE

AGRICULTURE

THE ILLINOIS SOYBEAN CHECK-OFF AND ITS IMPLICATIONS TO RESEARCH AND SCIENCE, William D. Tiberend, Manager, Illinois Soybean Program Operating Board, Bloomington, 62901. In the state of Illinois, soybeans are a major cash crop and the leading dollar earner in the export market. Illinois acreage has increased to over 8 million acres in 1975. While this spectacular growth in soybean production was taking place, the increase in the pool of knowledge available to the soybean producers on production and utilization lagged behind. To help in solving their problems, farm leaders developed a new, self-help program called a soybean checkoff. Through enabling legislation, a law was passed allowing for the drafting of a program to be submitted to all soybean producers for approval by referendum. The development of such a program was finalized and approved in a referendum by Illinois soybean farmers on July 16, 1974. The checkoff program was implemented on September 1, 1974. It required that all soybeans produced and marketed in Illinois have the checkoff made at the first point of sale. The program required ¼¢ per bushel be deducted during the first year, and no more than ½¢ per bushel in all subsequent years. The program established an 18 member board from equal districts around the state and charged them with administering the program. The program further required that funds collected be used only for production and utilization research, and market development. The program did, however, allow any producer to request and receive a full refund of monies deducted. With the dollars generated, it is hoped that additional soybean research will be accomplished by providing necessary scientific equipment and supplies, and by supporting additional research associates and graduate students. With this additional support, hopefully, the number of scientists working on production and utilization problems will increase and the information generated will aid all areas of the soybean industry.

MODIFICATION OF CELL DEATH PATTERNS IN SOYBEAN STEMS BY FERTILIZATION TREATMENTS, A. J. Pappelis, George Kapusta, and G. A. Pappelis, Southern Illinois University, Carbondale, 62901. Almost all of the internodal pith cells of the lower 10 internodes were dead on both sampling dates (about 2 and 3 months after planting, respectively) in Wayne and Clark. Pith cells in lower nodal regions died before those in upper nodal regions. Addition of nitrogen, phosphorous, and potassium always reduced the number of nodes with dead pith cells linking areas of dead pith cells in adjacent internodes. At 2 months after planting, the reductions were: Clark, from 29% of the nodes dead to 8%; and Wayne, from 36% to 12%. At 3 months after planting, the reductions were: Clark, from 50% to 16%; and, Wayne, from 51% to 22%. Similar effects were noted in the same plots in the following year with no added fertilizer.

CELL DEATH RATING SYSTEM FOR SOYBEAN PITH TISSUE, A. J. Pappelis and Kuo-Chun Liu, Southern Illinois University, Carbondale 62901. A rating system based on areas of dead, white cells in internodes and nodes was developed to document patterns of cell death in stems of maturing soybeans. The cell death patterns in internodal pith appears to be similar in all cultivars studied but the rate of cell death differs. The pattern of pith cell death in nodal regions is like that described for the pattern of spread of brown stem rot symptons; both occuring first in the lower stem and a slow upward movement follows. Symptoms of brown stem rot in the field (natural infections) and in the greenhouse following inoculation appeared to be limited to areas of dead internodal pith by the presence of living pith tissue in nodal regions.

EFFECT OF TEMPERATURE AND OSMOTIC CONCENTRATION ON COTYLEDON CRACKING DURING IMBIBITION OF SOYBEAN, M. E. Sorrells and A. J. Pappelis, Southern Illinois University, Carbondale, 62901. Soybeans seeds (Williams and Clark 63), imbibed at 10, 30, and 50 C exhibited extensive injury (transverse and crescent cracks): first at 50 C (within 45 minutes) and least 10 C (after 5 hours). After 12 hours more than 50% of the cotyledons had cracked regardless of temperature. When imbibed in manitol solutions (0.1 M to 1.0 M in 0.1 M steps), most injury occured at 0.1 M (Williams, 53%; Clark 63, 20%) and less as molarity increased. Four of 28 cultivars were injured significantly less when imbibed in water (22 C for 12 hours). More than 85% of the cotyledons of 22 cultivars exhibited cracks. The least amount of damage was 29%. Response varied with seed source (3 cultivars studied).

NEED FOR A NATIONAL FOOD POLICY, Walter J. Wills and Donald W. Lybecker, Southern Illinois University, Carbondale, 62901. Illinois exports more corn and soybeans than any other state. This means the export market is vital to Illinois agriculture. Agriculture is one of the few U.S. industries with production efficiency that permits exports on world markets. U.S. consumers are concerned about the high costs of food and how increased agricultural exports would cause even higher food prices. On three occasions in recent years there have been government embargoes on U.S. agricultural exports. Such actions reduce our dependability as a source of supply in the eye of many would be buyers. A national food policy would contribute much to improved price stability, better farmer decision making, an improved agribusiness climate and a continued favorable balance of trade.

MULTIDISCIPLINARY APPROACH TO CURTAILING POPULATION GROWTH, Howard H. Olson, Southern Illinois University, Carbondale, 62901. World population growth is the greatest among the illiterate rural people of the developing countries. The effectiveness of population control measures among these poeple has been minimal. Observations in India and Egypt indicate the need for coordinated education and research programs which deal with all phases of life in these rural areas. Schemes to modernize agriculture in many of these lands may produce more food but it deprives people of their previous work and forces readjustment in their living habits and swells the urban areas. If there is ever to be a meaningful improvement in the level of human nutrition and living standards, agricultural scientists must work closely with nutritionists and family planning programs.

HORMONAL INITIATION OF LACTATION, C. L. Moore, Illinois State University, Normal, 61761. Estrogen, progesterone, dexamethasone and prolactin were used to initiate lactation in 4 Holstein cows and 4 heifers. 17β-estradiol and progesterone were injected subcutaneously 2 times daily for 7 consecutive days. Dexamethasone was injected intramuscularly once daily on days 7, 8 and 9 after the est.-prog. injection. Prolactin was injected either subcutaneously or directly into 2 mammary quarters on days 9 and 10 after the last est.-prog. injection. The addition of dexamethasone and prolactin in the est.-prog. injection series did not give any improvement in the production performance of animals induced to lactate. Near normal production was obtained in 3 cows but in none of the heifers. Peak production among the cows and heifers was 32 and 12 kg milk/day, respectively.

DIFFERENCES IN MARE AND FOAL ORAL SMEARS, Carolyn F. M. Kamarasy and A. J. Pappelis, Southern Illinois University, Carbondale, 62901. Mares had consistantly higher cellular maturation scores (Cell Development Index, Karyopycnotic Index, and Maturation Index) than that of foals. The maturation indices increased in mares from May through July, suggesting summer (long-day) associated changes in oral smears. Rapid increases in the maturation indices occurred in foals during the first two weeks after birth. We infer hormonal changes are associated with changes in oral smears in both mares and foals.

FERMENTATION PROPERTIES OF SAWDUST SILAGE, D. E. Short, F. C. Hinds, and T. R. Yocum, University of Illinois, Urbana, 61801. A 4X2X2 factorial *in vitro* experiment was conducted to determine the effect of concentrate (C) level and source of moisture (M) upon the fermentation properties of cottonwood sawdust silage. The C fraction was provided by ground shelled corn at levels of 20, 40, 60, and 80% of the dry matter. Water or cattle oxidation ditch mixed liquor (ODML), with or without 10% sodium lignin sulfonate (SLS) was added to increase the final M level between 60-65%. In general as the level of C increased or SLS replaced 10% of the M source lactic acid (LA) production increased and the pH of expressed juice declined. When compared to water, ODML increased both LA and pH values. Fermentation was essentially complete after 7 days; however, some changes were observed between values at 7 and 21 days.

COMBINING TWIN AND HALF-SIB PROGENY TESTS IN BLACK WALNUT, Fan H. Kung and Calvin F. Bey, Southern Illinois University and Forest Service, USDA, Carbondale, Illinois, 62901. Just as twin studies in cattle have been useful in separating genetic and environmental effects, the procedure is also useful for black walnut trees. Twin trees were produced by longitudinally splitting germinating seeds and growing each half. By nesting twins within a half-sib progeny test, we obtained estimates on additive and dominance genetic variance components. Twins from 23 parent trees in southern Illinois are under study. Almost all of the genetic variance is additive and half-sib family selection seems to be the most promising approach.

ALLIUM VINEALE: ITS PERENNATING NATURE AND CONTROL ASPECTS. George Kapusta, Southern Illinois University - Carbondale, 62901. Three studies were conducted in 1974-1975 to evaluate Allium vineale control in soft winter wheat with herbicides. Banvel and 2,4-D ester at 1.0, 2.0 and 4.0 pt/A were fall-applied at three stages: preplant incorporated, preemergence, and topical postemergence. Spring-applied post-emergence treatments included 2,4-D ester, 2,4-D amine, Banvel, 2,4-D ester + dicamba, 2,4-D ester + Furlow, and 2,4-D amine + dicamba. Crop stand injury and reduction, crop yield, and aerial bulbils per 200 or 500 g wheat were determined. Preplant incorporated 2,4-D ester and Banvel both reduced harvested bulbils without incurring wheat injury. Preemergence applied 2,4-D ester also reduced harvested bulbils but Banvel was ineffective. Fall postemergence applied 2,4-D ester and Banvel also reduced harvested bulbils. Spring applications generally were less effective than fall applications in this study.

A NUTRITIVE VALUE COMPARISON OF FIVE MIDWESTERN FORAGES, R. A. Dvorak, D. A. Miller, and F. C. Hinds, University of Illinois, Urbana, 61801. Changes in the chemical composition and nutritive value of alfalfa, smooth bromegrass, orchardgrass, tall fescue, and reed canarygrass were observed over a range of maturities. Samples of each specie were harvested at weekly intervals from April 28 thru June 23. The Van Soest scheme of cell wall analysis was used to describe chemical composition. The Barnes modification of the Tilley and Terry *in vitro* technique was compared with Van Soest's summative equation to estimate nutritive value. Dry matter digestibility differences between grass species were primarily due to differences in cellulose and silica content. Alfalfa contained considerably less hemicellulose than the grasses and was most digestible at all stages of maturity.

MECHANISM OF ACTION OF MBR-12325 ON *FESTUCA ARUNDINACEAE*. M. A. Briskovich, D. M. Elkins, and J. H. Yopp. Southern Illinois University, Carbondale, 62901. *Festuca arundinaceae* grown in sand culture in the greenhouse, was clipped to 7 cm and treated with 0.56 and 1.12 kg ai/ha MBR-12325. Morphological parameters measured or calculated were leaf width, midrib thickness, volume of roots, root length, dry weight roots, dry weight leaves, root/shoot, height, number of leaves, number of tillers, leaves per tiller, and weight per leaf. The root/shoot was most radically affected. Root studies indicated that the primary mode of action was not in the roots. Interaction studies with GA_3, Kinetin, Actinomycin-D, cycloheximide, and IAA showed IAA to be antagonistic to MBR-12325.

EFFECT OF PLANTING DATE ON DEVELOPMENTAL STAGES IN SORGHUM, Oval Myers, Jr., George Kapusta and Mark E. Sorrells. Southern Illinois University, Carbondale, 62901. Three sorghum cultivars, Pioneer 866, 846, and 828, each known to differ in date of flowering by approximately five days from the other, respectively, at a mid-June planting date, were planted at the SIU-C Belleville Research Center on five dates: May 25, June 11, June 24, July 8 and July 23, 1974. The experimental design was a split-plot with three replications. Dates of floral initiation, flowering and black layer maturity were determined. An analysis of variance showed statistically significant differences at the 5% probability level for date of planting, cultivars and date of planting X cultivar interaction for all three growth stages except for cultivars in the number of days from floral initiation to flowering which was significant at the 10% probability level.

GROWTH REGULATORS IN CONJUNCTION WITH ADJUVANTS ON HEGG POINSETTIAS, Robert Holmes and Randey Wall, Southern Illinois University, Carbondale, 62901. A spreader-extender, Exhalt, and a spreader-activator, Regulaid, were used at two rates with the growth regulators, A-Rest and B-Nine, on 'White Annette Hegg' and 'Dark Red Annette Hegg' poinsettias. Applications were single treatments of foliar spray to runoff. Height at time of application, final height, bract diameter, and date of anthesis were recorded. Bract diameter was decreased with A-Rest. Some delay in anthesis was experienced with the growth regulator treatments. A-Rest was much more effective in height reduction than B-Nine at these rates. The lowest rate of B-Nine resulted in significantly taller plants than the control. The adjuvants had no effect on height, date of anthesis, or bract diameter.

EFFECT OF CHEMICAL POLLEN CONTROL AGENT ON EASTER LILIES, R. C. Cain and G. D. Coorts, Southern Illinois University, Carbondale, 62901. Investigations were carried out utilizing a split-plot design with chemical pollen control agent (DPX 3778) within sticker-extender (Exalt 800) on 'Ace' and 'Nellie White' Easter lily. The chemical pollen control agent had no effect upon the anthers, or the pollen of the lily flowers treated, but reduced flower opening and longevity with increasing concentration. At the highest levels used (6-, 8-, and 10,000 ppm) anther exertion was prevented. The sticker-extender had no detrimental effect when used at the recommended concentration and appeared to increase the effect of the chemical pollen control agent when used in combination.

THE EFFECT OF N SOURCE ON THE GROWTH OF CHRYSANTHEMUM MORIFOLIUM CV DEEP MERMAID, Ray Maleike and Richard Lindstrom, Southern Illinois University, Carbondale, 62901 and VPI & SU, Blacksburg, VA, 24061. Chrysanthemum morifolium 'Deep Mermaid' was grown in water culture with equivalent concentrations of N as NH_4, NO_3, and NH_4+NO_3. Various growth parameters and mineral composition were determined after a 44-day long day period and 28 days of short days. Dry weight, stem length, number of shoot breaks, root length and root weight were reduced under NH_4-N in comparison to NO_3-N. There was an increase in root length, number of breaks and dry weight under the combined N treatments. Leaf levels P, B, N and Cu were decreased by NO_3 nutrition. NH_4 nutrition decreased leaf Ca, K, and Mn and root Ca. A reduction in plant quality from a marginal chlorosis was observed on all plants receiving the NH_4 ion in the nutrient solution.

A HISTORY OF BRYOLOGICAL STUDIES IN ILLINOIS, R.E. Stotler, Southern Illinois University, Carbondale, 62901. The earliest publications to record bryophytes native to Illinois were issued in 1859 when two moss papers actually appeared within the same journal. Subsequent to these initial lists few actual survey accounts from throughout the state have been forthcoming. Treatments in recent times have been restricted to local or regional considerations.

AN AUTECOLOGICAL INVESTIGATION OF SELECTED BRYOPHYTES IN THREE SANDSTONE CANYONS IN SOUTHERN ILLINOIS. Douglas Zehr, Southern Illinois University, Carbondale, 62901. An autecological study of the microhabitat of selected bryophytes in three sandstone canyon areas in southern Illinois was undertaken. Light energy, relative humidity, plant surface temperature, and soil pH were investigated. Recognizable differences in requirements for these microhabitat features were observed.

TAXONOMIC COMPOSITION AND STANDING CROP OF BRYOPHYTES OF A WET-TUNDRA-MEADOW COMMUNITY IN THE VICINITY OF BARROW, ALASKA, James R. Rastorfer, Chicago State University, Chicago, Ill. 60628. Sample cores were collected periodically from three plots for analyses. The bryophyte synusia consisted of about 30 taxa with nearly equal numbers of leafy liverworts, acrocarpous mosses and pleurocarpous mosses, whereas the standing crop consisted of 3%, 20% and 77% for these three groups, respectively. Dominant species were Campylium stellatum and Calliergon sarmentosum that comprised 69% of the bryophyte standing crop which increased from 115 to 142 g per sq m over a 63 day period. Bryophytes are major components in many tundra plant communities. This work was a U.S. Tundra Biome Project.

DEVELOPMENTAL PATTERNS OF THE LIVERWORT *GYROTHYRA UNDERWOODIANA* HOWE. Barbara Crandall-Stotler, Southern Illinois University, Carbondale, 62901. A unique combination of morphological characters and a restricted, endemic distribution in western North America makes *Gyrothyra underwoodiana* a phylogenetically interesting taxon. To understand the biology of this exotic plant, patterns of sporophyte, sporeling, and gemmling development were studied in natural and axenically cultured populations. Using the methods of serial microtome sectioning, division sequences for all 3 developmental pathways have been elucidated and the intergeneric relationships of *Gyrothyra* have been clarified.

DEVELOPMENTAL ANATOMY IN THE LEAFY LIVERWORT, *NOWELLIA CURVIFOLIA* (DICKS.) MITT. Marleen Schertler, Southern Illinois University, Carbondale 62901. The developmental anatomy of *Nowellia curvifolia* was studied using the techniques of serial microtome sectioning at the light microscope level. The ontogeny of sporelings and gemmlings have been studied in axenic culture, and water sac formation from leaf initials has been elucidated. Using such data, the phylogenetic relationships of this key taxon in the Cephaloziaceae have been substantiated.

TRENDS OF SPECIALIZATION IN THE LEAVES OF NEW WORLD GESNERIACEAE Richard C. Keating, Southern Illinois University, Edwardsville, 62026. The Gesneriaceae, a tropical flowering plant family comprised of terrestrial and epiphytic herbs, were studied to determine the evolutionary trends in their leaf anatomy. Species with large, oppositely arranged leaves have less specialized anatomy than those with small, alternate-leaved, pendent stems. The epidermis varies from a single cell layer to a deep, multicellular peripheral water storage tissue on the adaxial side. This water storage tissue may comprise up to 7/8 of the total leaf thickness. Chloroplasts may be evenly distributed in the mesophyll or restricted to the single palisade layer in the most advanced forms. Parallel specializations are common and most genera cannot be distinguished on the basis of their leaf anatomy.

THE ULTRASTRUCTURE OF MITOSIS IN PHACUS LONGICAUDUS (EUGLENACEAE), Kenneth L. Weik, Lake Forest College, Lake Forest, Illinois 60045. Recent investigations at the ultrastructural level reveal that basal body and early pellicle replication precede mitosis in Phacus longicaudus. Although basal bodies appear not to play a role in spindle formation, their association with distinct rhizoplasts may be responsible for partitioning of daughter nuclei in cleaving cells. Formation of daughter nuclei is accompanied by separation of the nuclei from the interzonal spindle. The spindle together with its ensheathing remnant of nuclear envelope persist for some time in the intervening cytoplasm.

CLAMP CONNECTIONS IN BASIDIOCARPS AND TISSUE CULTURES OF CHLOROPHYLLUM MOLYBDITES, Walter J. Sundberg and John M. Halbrendt, Department of Botany, Southern Illinois University, Carbondale, Il 62901. Contrary to most published data, clamp connections, although infrequent and never at every septum, were found in all (over 60) basidiocarps of Chlorophyllum molybdites (Meyer ex Fr.) Massee examined from throughout much of the United States. Observation of over 3,500 hyphal septa in four tissue culture isolates revealed that clamps were irregularly distributed along the length of the hyphal system and occurred at about 10% of the septa. A reduction in clamp frequency was noted with a decrease in medium strength. Therefore, the absence of clamp connections can no longer be utilized to support generic segregation of Chlorophyllum from Lepiota sensu lato.

SOME POLYPORES CAUSING DECAY OF EASTERN REDCEDAR (JUNIPERUS VIRGINIANA), K.A. West, Illinois Dept. of Conservation, Benton 62812. Eastern redcedar or juniper, an important species of abandoned fields and ridgetops in Illinois, possesses very decay resistant wood. Among the few fungi which can degrade juniper wood are three polypores: Daedalea juniperina, Fomes roseus, and Lenzites saepiaria. These species are not common throughout the range of redcedar in Illinois. Apparently age of individual trees and site conditions are important factors in the distribution of these fungal associates.

NECROSIS AND EARLY LEAF FALL CAUSED BY FOLIAR DISEASES PRECLUDE AUTUMN COLORATION IN EASTERN COTTONWOOD, J. J. Jokela and E. J. Zegar, University of Illinois, Urbana, 61801. Observations in experimental plantings and wild stands of eastern cottonwood indicate that heavy infections of Marssonina and Melampsora leaf diseases occur annually in Illinois. Necrosis and premature defoliation reduce vigor and preclude the development of yellow autumn coloration characteristic of poplars. Naturally occurring resistant trees can be cloned and utilized for reforestation and amenity plantings.

THE PRESETTLEMENT VEGETATION OF LAKE COUNTY, ILLINOIS, Robbin C. Moran, Lake County Forest Preserve District, Libertyville, 60048. The original land survey records made in the late 1830's were used to determine the composition and distribution of vegetation prior to settlement in Lake County, Illinois. A presettlement map of the county is proposed showing seven general community types: wet prairie, mesic prairie, swamp or marsh, tamarack bog, oak savanna, oak-hickory and maple-basswood forest. Most of the county was covered by savanna that was dominated by bur oak with white oak as a co-dominant. Prairie was most extensive west of the Des Plaines River, with forest occurring east of the river and in places that were protected from prairie fires. Glacial history and fire were important environmental factors in the distribution and compostion of the plant communities.

EFFECTS OF STRIPMINE pH AND SOIL CONDUCTIVITY ON PLANT DISTRIBUTIONS, W. C. ASHBY, C. A. KOLAR, AND M. J. DAY, Southern Illinois University, Carbondale, 62901. A barren stripmine area graded, limed, fertilized, seeded, and mulched in 1972 was again 50% barren in 1975. Soil samples on plots including the well and poorly vegetated areas ranged from pH 2.2 to 8.1, and from 0.05 to 4.60 mmho/cm conductivity. Presence or absence of annual lespedeza, sericea lespedeza, Canada bluegrass, tall fescue, broomsedge, and redtop accounted for 43 to 61% of the variance in pH on the 3 plots, and for 20 to 35% of the variance in soil conductivity using standard multiple regression techniques. Another 14 species contributed a non-significant amount of additional R^2. Broomsedge was associated with the most acidic vegetated areas, and annual lespedeza with the least.

EFFECTS OF LIVESTOCK WASTE ON SEED GERMINATION, SEEDLING SURVIVAL AND GROWTH OF SHORTLEAF (PINUS ECHINATA MILL.) AND LOBLOLLY PINE (PINUS TAEDA L.), Marla McIntosh and G.L. Rolfe, University of Illinois, Urbana, 61801. This study was designed to evaluate the possible effects of disposal of livestock waste in forested environments on seed germination and consequent seedling growth and survival. Beef cattle waste was incorporated into a nutrient deficient soil in a range of concentrations. Germination and seedling survival of both pine species were significantly reduced by the addition of waste. However, total seedling biomass and nitrogen content of the surviving seedlings were higher than the controls, while Ca, Mg, and K were not significantly affected.

ADDITIONS TO THE VASCULAR FLORA OF GREENE COUNTY, ILLINOIS, R. D. Henry and A. R. Scott, Western Illinois University, Macomb, 61455. Vascular plant collections made from the summer of 1973 through the fall of 1975 resulted in the addition of 102 species to the previously published 545 species for Greene County, Illinois. Of the 102 species reported 65% were native and 35% were alien plants. Dipsacus laciniatus L. and Rudbeckia amplexicaulis Vahl were noteworthy with respect to their habitat.

WOODY VEGETATION SURVEY OF A TERRACE FOREST IN EAST-CENTRAL ILLINOIS, Randy W. Nyboer and John E. Ebinger, Eastern Illinois University, Charleston, 61920. A total of 47 species of woody plants were found during a vegetation survey of a terrace forest in Clark County, Illinois. Two distinct vegetation zones (low and high terrace) occur on the woodlot and their composition and ecological trends are discussed. Woody species of the low terrace average 140 stems with a basal area of 125 square feet per acre. It is dominated by buckeye, box elder, hackberry, sycamore, silver maple and black walnut in order of Importance Value. The high terrace is dominated by shellbark hickory, box elder, white oak,white ash, and red maple. Here the arborescent species average 126 stems per acre with a basal area of 113 square feet.

CULTURE OF TOMATO CALLUS FROM STEMS AND FRUITS, Lewis Dove and Susan Hale, Western Illinois University, Macomb, 61455. Plant tumors (callus) formed on fruit and stem segments cultured on a defined medium having equal concentrations of indoleacetic acid (IAA) and kinetin. Growth subsided within 4 weeks following fruit segment transfer. Ripening occurred without IAA or kinetin; these regulators maintained other segments in a green condition for 24 weeks. Stem callus was subcultered every 8 weeks for 32 weeks. Three ppm kinetin and IAA produced the fastest growth; high IAA/kinetin ratios caused root formation, but low ratios failed to stimulate shoot development. Supplementing the basic medium with additional vitamins and more frequent transfers failed to change the basic growth patterns or growth rates of the cultures.

CHROMATOGRAPHY OF CHLOROPLAST PIGMENTS ON A THIN LAYER OF SUCROSE, Kent A. Retzer, Illinois State University, Normal, 61761. A technique for preparation of microchromatoplates with a thin layer of sucrose as adsorbent and for use of these plates in separation of fat soluble chloroplast pigments of Pelargonium using only basic lab equipment has been developed. By passing a glass plate closely over microscope slides, the slides were coated with a slurry of confectioner's sugar in methanol. These coated slides were used for thin layer chromatography in an inverted beaker chamber. This method produced a uniform layer of 250 to 400 μ which, when used with 0.5% n-propanol in petroleum ether, separated chloroplast pigments rapidly and effectively. This technique may be used in research and general instruction.

COMPARISON OF CHLOROPHYLL CONTENTS, HILL REACTIONS, NUMBER OF CHLOROPLASTS IN GUARD CELLS AND LENGTHS OF GUARD CELLS IN DIPLOID AND TETRAPLOID PLANTS OF TRADESCANTIA OHIENSIS, James Walter, James R. Rastorfer and O. J. Eigsti, Chicago State University, Chicago, Ill. 60628. Naturally occurring 2n and 4n plants were grown under identical conditions. Chlorophyll contents ($\mu g/cm^2$) were 57 and 50 for the 2n and 4n plants respectively. Hill activities (Absorbance/cm^2) tended to be higher in the 2n plants than in the 4n plants amounting to 3.13 and 2.86. In contrast, the 2n plants tended to have fewer chloroplasts per guard cell than the 4n plants numbering 26.9 and 32.2. Lengths of the guard cells were 54.7 μm for the 2n plants and 63.5 μm for the 4n plants. Based on these parameters, there is no appreciable difference between the 2n and 4n plants.

COLLEGIATE CHEMISTRY

INFRARED STUDIES OF SOME SUBSTITUTED CYCLOHEXENES, Linda Sheely and Leland Harris, Knox College, Galesburg, 61401. The infrared analysis of a series of substituted 3,4-dimethyl-6-phenyl-3-cyclohexene-1-carboxylic acids was accomplished through the use of high resolution IR methods. The highly substituted cyclohexenes were synthesized with a Diels-Alder reaction involving 2,3-dimethyl-1,4-butadiene and an analog of trans-cinnamic acid, bearing various substituents on the phenyl ring. Evaluation of the data not only substantiated the structures of these compounds, but also gave some interesting insights into the conformation of substituted cyclohexenes.

THE SIU-C HISTORY OF CHEMISTRY EUROPEAN SUMMER TOURS. John H. Wotiz, Department of Chemistry & Biochemistry, Southern Illinois University, Carbondale, IL 62901. The SIU-C sponsored tours in Western and Central Europe were successfully carried out in 1971-73-75. It provided unique educational opportunities and experience for the participants. They were mostly secondary school teachers and college instructors who wanted to introduce history and the human aspect of chemistry and science into their courses. Itineraries and programs were established over the years that included most of the places where history of chemistry was made, is on exhibit, and visited the historians who lectured in their field of specialties. Efforts were made to avoid repetitions of specialized lectures. Although the cost of programs increased over the years, it still combines an inexpensive way to secure professional competence with an opportunity for tourism. Color slides will be shown.

SYNTHESIS OF DIELS-ALDER ADDUCTS OF SUBSTITUTED IODOCINNAMIC ACID, Glenn Londos and Leland Harris, Knox College, Galesburg, 61401. Diels-Alder adducts of the substituted iodocinnamic acids were prepared in our laboratories. Substituted iodotoluenes were added to chromium oxychloride and then refluxed for 12 hours to produce the substituted iodocinnamic acids. The substituted cinnamic acids were reacted in a bomb with 2,3-dimethyl-1,3,-butadiene for the subsequent adduct formation; 2 (m- and p-iodophenyl)-4,5-dimethyl-1,4-tetrahydrobenzoic acids.

ISOMERIZATION OF 1,4,-DI-T-BUTYLBENZENE

David Buchanan and K. E. Kolb, Bradley University, Peoria, Illinois 61625

The study of the t-butyl derivatives of benzene has continued. Last year at the 67th annual meeting of the ILLINOIS STATE ACADEMY, Neuman and Kolb reported a direct synthesis of 1,3,5-t-butylbenzene from benzene and t-butyl chloride. The work has now been extended to determine the effect of $AlCl_3$ and $AlCl_3$ complexed with various reagents, e.g. nitrobenzene, hexamethylbenzene, on 1,4-di-t-butylbenzene. With $AlCl_3$ complexed with nitrobenzene the major product is the isomer 1,3-di-t-butylbenzene. If the 1,4 isomer is treated in benzene with $AlCl_3$ over 98% t-butyl benzene is produced in 16 hrs. at 20°.

Cu/Zn IN LEUKEMIC BLOOD, Catherine Harbert, James Hazdra, Edward Zbella, Glen Coulomb, Illinois Benedictine College, Lisle, Illinois, 60532. Cu and Zn determinations were performed on the blood serum of chronic and acute leukemic humans, mice and fish by atomic absorbtion (air-acetylene flame), with a 1:5 dilution factor of H_2O at 326.5 and 214.05 nm, respectively. Literature cited indicates an abnormally high serum Cu level of leukemic humans, but only a 61% correlation with the number of blast cells in the bone marrow. Contrastingly depressed and elevated Zn levels in leukemic blood have been cited, with Zn levels from 24 to 30% lower than normal reported in patients' serum with various malignancies. By comparing a Cu/Zn ratio of serum levels, it is hoped that this test may prove successful as an indicator of remission or relapse before an observed bone marrow indication in leukemic patients.

TRACE ANALYSIS IN THE ILLINOIS RIVER NEAR PEORIA.

Eileen Venzon and M. A. Taylor, Department of Chemistry, Bradley University, Peoria, Illinois 61625

The results of a one and a half year study of trace contaminants found in the Illinois River near Peoria will be discussed. Sampling procedures were chosen to minimize the effects of inhomogenity in the river flow. Particular attention was paid to preservation and storage of samples. Regular analysis was done for COD, Cl^-, NO_3^-, NO_2^-, PO_4^{-3}, Mn, Fe, Ca, K, Cu, Pb. In addition, analysis of sediment samples for metals and water samples for Br^- were often completed. The analytical procedures used will also be discussed.

A STUDY OF THE PHOTOINITIATION OF CERTAIN ACRYLIC ESTER POLYMERIZATIONS, Mark S. Pucci, Department of Chemistry, Illinois Benedictine College, Lisle.

The objective of this study is to establish the electronic nature of primary free radicals which best initiate the polymerization reaction of certain acrylic ester systems. The primary free radicals which will be studied result from the reaction of photo-excited benzophenone with appropriate hydrogen donating species.

2-PYRIDYLCARBINOL N-OXIDE COMPLEXES OF TRANSITION METAL NITRATES. Chet A. Frank and Douglas X. West, Illinois State University, Normal, 61761. The ligand 2-pyridylcarbinol N-oxide combines with transition metal ions in both a monodentate and bidentate fashion. By using transition metal ion nitrates and varying the relative amount of the N-oxide ligand we have prepared a number of different complexes, some of which involve the various types of nitrate. That is, ionic nitrate and coordinated nitrate, monodentate and bidentate, examples have been secured. The characterization of the substances by elemental analyses, infrared spectra, solid and solution state visible and ultraviolet spectra, and molecular conductivities will be reported. A comparison of these complexes to those prepared from the metal ion perchlorates (J. Inorg. Nucl. Chem., in press) and tetrafluoroborates is anticipated.

NUCLEOPHILIC REACTIONS AT GERMANIUM(II) SITES, Louis Anasinis and P. S. Poskozim, Chemistry Department, Northeastern Illinois Univ., Chicago, IL 60625. Reactions of strong nucleophiles such as RLi and RMgX with formally germanium(IV) compounds are well studied. $GeCl_4$ is a common starting material. Little is known about

(1) Excess RLi + $GeCl_4$ $\rightarrow$ GeR_4 + some Ge_2R_6

parallel reactions with germanium(II) halide starting materials. Convenient germanium(II) starting materials are the trichlorogermanate(II) salts, $MGeCl_3$ (M = a large cation such as Cs^+, Rb^+, Me_3NH^+, etc.). Evidence to date points to the following reaction.

(2) Excess PhLi + $CsGeCl_3$ $\rightarrow$ $GePh_4$ + some Ph-Ph + some polymer

Probable pathways to the observed products will be presented.

TRACE METALS IN CANCEROUS TISSUE, Mark S. Pucci, Department of Chemistry, Illinois Benedictine College, Lisle.

A study of trace metal in normal and cancerous mice was conducted using atomic absorption spectroscopy. Tissue of the spleen, thymus, and lymph nodes were digested and analyzed to ascertain whether or not there is any difference in trace metal content between normal and cancerous tissue. It is hoped that this analysis could be used as a diagnostic method for determining benign or malignant tumors.

MANNICH CONDENSATIONS OF 4-SUBSTITUTED RESORCINOLS. Gordon Dean Weatherbee and Carl Weatherbee, Department of Chemistry, Millikin University, Decatur, Illinois 62522.

Condensation of secondary amines, formaldehyde, and 2,4-dihydroxyacetophenone in equimole ratio give 3-substituted derivatives and not 5-substituted compounds. Although acetophenone readily undergoes the Mannich Condensation, the methylketone of 2,4-dihydroxyacetophenone did not undergo condensation with reaction conditions employed in this investigation. Structural determinations and nmr studies of products secured in Mannich Condensations involving 4-substituted resorcinols will be discussed.

METAL ION COMPLEXES PREPARED FROM THE SODIUM SALT OF A SUBSTITUTED 1-HYDROXYPYRAZOLE 2-OXIDE, Susan P. McCormick, John F. Hansen and Douglas X. West, Illinois State University, Normal, 61761. Synthesis of a substituted 1-hydroxypyrazole 2-oxide, sodium salt, has yielded a potentially very interesting bidentate ligand. The metal perchlorates have been used for the preparation of the complexes in aqueous solution. The characterization of the compounds based on their partial elemental analyses, infrared spectra, visible and ultraviolet spectra will be discussed.

MANNICH CONDENSATIONS OF PHENOLS AND AMINE EXCHANGE REACTIONS. Norman Hoback, Lisa Lynn Reiger, and Carl Weatherbee, Department of Chemistry, Millikin University, Decatur, Illinois 62522.

The effect of pH on the yields of products secured by Mannich Condensations of amines, formaldehyde, and phenolic compounds was studied.

The feasibility of using amine exchange reactions in lieu of Mannich Condensations to prepare desired compounds was investigated.

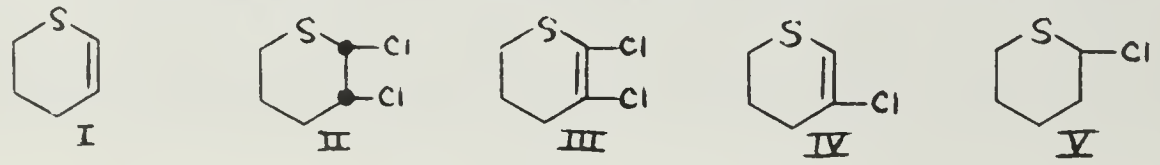
A STUDY OF THE RELATIONALSHIP BETWEEN THE STRUCTURE OF A CHEMOTHERAPY COMPOUND AND ITS EFFECTIVENESS AS AN ANTITUMOR AGENT. Sidney T. Smith, Mark G. Matlock and Carl Weatherbee, Department of Chemistry, Millikin University, Decatur, Illinois 62522.

To aid in predicting new chemotheraphy compounds, the effectiveness of previously prepared compounds was studied as a function of structure with view of determining a correlation of effectiveness and structure. One of the principal compounds studied was the Weatherbee Mustard.

Chemotherapy information about several compounds prepared in our laboratories will be presented.

A PRODUCT STUDY OF CHLORINE ADDITION TO 3,4-DIHYDRO-2H-THIOPYRAN UNDER FREE RADICAL CONDITIONS. William Becker & Fred Breitbeil, DePaul U., Dept. of Chem., Chi., Ill.60614

Chlorine was added to 3,4-dihydro-2H-thiopyran (I) at -15° under irradiation in the absence of oxygen. The major product was cis-2,3-dichlorothiopyran (II). The trans isomer and 2,3-dichloro-3,4-dihydro-2H-thiopyran (III) are minor products. On heating, the 2,3-dichlorothiopyrans yield 3-chloro-3,4-dihydro-2H-thiopyran (IV). Addition of chlorine to IV yields III and addition of HCl to I yields 2-chloro-3,4-dihydro-2H-thiopyran (V). Results of the reaction of HCl with IV and III will also be discussed.



SUGAR COMPOSITIONS OF CELL ENVELOPES FROM TWO STRAINS OF SERRATIA MARCESCENS, Jeffrey Landes and Joseph C. Tsang, Illinois State University, Normal, 61761. Isolated cell envelopes (ICE) of S. marcescens strains 08 and Bizio were analysed for their sugar compositions by the alditol-acetate method in a gas chromatograph. Hydrolysis in 3N HCl at 100 C for various time periods indicated that 1 hr hydrolysis resulted in incomplete release of L-rhamnose and D-glucosamine. Although D-glucosamine was completely released after 3 hr hydrolysis, the neutral sugars were degraded. With 2 hr hydrolysis, ICE from 08 gave D-ribose, D-galactose, D-glucose, D-glycero-D-mannoheptose, and D-glucosamine in a molar ratio of 2:3:6:2:7. Similarly, ICE of Bizio gave L-rhamnose, D-ribose, D-mannose, D-glucose, D-glycero-D-mannoheptose, L-glycero-D-mannoheptose, and D-glucosamine in a molar ratio of 31:18:3:25:6:2:3. These results indicate that sugar compositions of cell envelopes from different strains of S. marcescens may not be the same. Work is in progress to confirm this suggestion by analyzing the lipopolysaccharide

INTERACTION BETWEEN DNA, HISTONES AND NON HISTONE CHROMATIN PROTEIN, J. Jeffery Krug and Elaine Z. Herzog, Department of Chemistry, University of Illinois Chicago Circle, Chicago, 60680. A model system has been developed in which the nuclear events leading to repression and derepression of DNA may be studied. DNA-cellulose was placed in a column and histones were absorbed from a solutionpassed through the column. Subsequent passage of non histone protein through the column resulted in the elution of histones. This supports the hypothesis that histones are the repressors, and that non histone proteins can act as derepressors.

INHIBITION OF RAT LIVER PROTEIN SYNTHESIS BY CARBON TETRACHLORIDE. G. Hortin, G. Ricca, J. Markese, and A. Richardson, Depts. of Chemistry and Biological Sciences, Ill. State Univ., Normal, 61761. CCl_4 administered to rats orally (0.2 ml/100 gm body wt) inhibited cell-free protein synthesis up to 60% in a postmitochondrial supernatant (PMS) system prepared from liver. Maximal inhibition occurred within 3 hr after CCl_4 dosing; recovery ensued within 24 hr. CCl_4 added directly to the PMS had no effect on protein synthesis. When CCl_4 was present in a liver slice system, it inhibited protein synthesis up to 70% suggesting that cells must be intact to potentiate the inhibition. Ribosomes from the PMS of CCl_4-poisoned rats had an impaired ability to incorporate amino acids while the cell sap lost little of its ability to sustain incorporation. Polyinosinate reduced the PMS amino acid incorporation of control animals to that of CCl_4-poisoned animals suggesting that CCl_4 decreased the ability of ribosomes to participate in initiation.

TOTAL LACTIC DEHYDROGENASE AND ISOENZYMES OF HUMAN SENILE CATARACTS, Leon L. Gershbein and Teruki C.Dan, Northwest Institute for Medical Research, Chicago, 60634. Human senile nuclear cataracts removed at surgery were dissected to yield the nuclei or central cores and the more transparent peripheral portions. Each section was homogenized with 0.90% saline (1:10, w/v), centrifuged at 45,000 x g at 10° and the supernatant fluids analyzed for various glycolytic enzymes. Of the latter, the mean lactic dehydrogenase (LDH) ± standard error of the mean for 25 cataracts amounted to 31.7 ± 4.8 and 445.9 ± 77.2 mU/mg for the nuclear and peripheral portions, respectively. The LDH isoenzymes for the nuclear extracts as determined by polyacrylamide disc electrophoresis were not too well demarcated but the zymograms of the peripheral tissue homogenates were relatively free of LDH_1 and with LDH_4 + LDH_5, components which reflect heightened glycolysis, amounting to over 80% of the total LDH activity.

COLLAGEN IN HUMAN WHOLE BLOOD. Robin Miller, H.R.Catchpole D.Grohlich and A. Bezkorovainy, Dept.Pathol., Univ.Ill Med. Ctr. and Biochem.Dept.,Rush Med.Coll., Chicago,Ill. 60612 Anticoagulated blood had twice the hydroxyproline level of either serum or plasma alone. Upon cell centrifugation OH-Pro was in highest concentration in the RBC-fraction. Indirect immunofluorenscence on sectioned clots and smears of un-anticoagulated blood was done using human anti-collagen antibody. The clot showed a diffuse reticulum of fluorescent fibrils; in the smear platelet groups were highly fluorescent, red cells more faintly. After collagenase no fluorescence was seen. Purity of the human tendon collagen D (least soluble)was checked by Ouchterlony immunodiffusion and amino acid analysis which produced an unusual residue, possibly of the rarer crosslinking types. (Support by Stetler Fdn., Am. Heart Assn.)

CHANGES IN ACIDIC AND NEUTRAL AMINO ACIDS IN CHICK BRAIN DURING DEVELOPMENT AND INDUCED PHENYLKETONURIA. Carol Krueger and Arlan Richardson, Dept. of Chemistry, Ill. State Univ., Normal, 61761.

The acid-soluble acidic and neutral amino acids in chick brain were analyzed. The cerebrum, cerebellum, and optic lobes of chicks at different ages were studied. No significant changes in the levels of any of the amino acids occurred with development or maturation. Nor were any significant differences in amino acid concentration of the three regions observed at any of the ages studied. A phenylketonuric-like plasma and tissue phenylalanine (phe)/tyrosine (tyr) imbalance was studied by feeding chicks diets containing high levels of phe and/or p-chlorophenylalanine (pCPA). The presence of pCPA prevents the metabolism of phe to tyr by inhibiting the enzyme phe hydroxylase. Results showed that both phe and pCPA were required to increase the phe/tyr ratio in tissue and plasma.

DIRECT DETERMINATION OF Km AND Vmax OF ALKALINE PHOSPHATASE IN POLYACRYLAMIDE GELS AFTER ELECTROPHORESIS, D. M. Kranz and J. C. Tsang, Illinois State University, Normal, IL. 61761. Alkaline phosphatase is found in bacteria and mammals. In the latter, many pathological conditions are known to be characterized by a change in the level of activity of this enzyme. However, a direct method for simultaneously assaying and characterizing the enzyme has not been available. In this study, we used SDS-polyacrylamide gel electrophoresis to separate the enzyme and subsequently determine its Km and Vmax in the gel. Gels were incubated in varying concentrations of the substrate, p-nitrophenyl phosphate and then scanned at 410nm for p-nitrophenol released. Areas of the absorbance peaks were used to construct the Lineweaver-Burke Plot from which Km and Vmax of the separated enzymes were determined. Using enzymes from E. coli and calf intestinal mucosa, this technique was found comparable to the routine procedure. This method is useful in characterizing crude enzyme preparations.

PROTEOSE-PEPTONE FRACTION FROM HUMAN MILK, Anatoly Bezkorovainy and James Nichols, Rush-Presbyterian-St. Luke's Medical Center, Chicago, Illinois 60612.
The proteose-peptone fraction of human milk was prepared as follows: defatted milk was heated at 95-100° for 30 minutes, the pH was adjusted to 4.6 and the precipitate removed and discarded and the supernatant dialyzed against distilled water and lyophilized. One hundred ml of milk yielded 100-200 mg. of proteose-peptone. The product was 8 times as active as milk in supporting the growth of L. Bifidus var. Penn and contained 24% carbohydrate. Its main component was a protein with the mobility of an α-1 globulin and a molecular weight of 10,000. Minor components included small glycoproteins, and proteinswith the mobility of β-globulins.

STUDIES OF PROPERTIES OF THE PIGMENT PRODUCED BY PULLULARIA PULLULANS. Emanuel Merdinger, Sava Mutafov and Charles F. Lange, Loyola University Stritch School of Medicine, Maywood, 60153 and Institute of Microbiology of the Bulgarian Academy of Sciences.

A number of solvents were found for the pigment produced by the fungus Pullularia pullulans, which for years was considered insoluble in many common organic and inorganic solvents. Paper and thin-layer chromatography of the pigment solutions revealed that the pigment consists of at least two colored portions, each with different properties. Each portion had a carbohydrate moiety.

DEVELOPMENT OF A BIOCHEMISTRY LABORATORY EXPERIMENT TO STUDY THE EFFECT OF ENVIRONMENTAL FACTORS ON THE FATTY ACID COMPOSITION OF LIVING CELLS. R. Clark, F. Lin, and A. Richardson, Dept. of Chem., Ill. State Univ., Normal, 61761. Most available biochemistry laboratory experiments on lipids have been limited to routine extraction and separation techniques. We have developed a system in which the effects of temperature, stage of growth, osmotic pressure, and medium composition on the fatty acid composition of yeast can be easily determined. The experiment is inexpensive and requires only one major piece of equipment, a gas-liquid chromatograph (GLC). The fatty acid composition of yeast consists primarily of C:14 to C:18 fatty acid which makes it possible to use a simple GLC system for the separation, identification, and quantification of yeast fatty acids. Because 98% of the fatty acids in yeast are found in membranous material, the effect of the environmental factors can be related to changes in the structure of the membrane.

NMR STUDIES OF SOME SUBSTITUTED CYCLOHEXENES, Dale Crockatt and Leland Harris, Knox College, Galesburg, 61401. The conformational analysis of a series of substituted 3,4-dimethyl-6-phenyl-3-cyclohexene-1-carboxylic acids was accomplished through the use of high resolution NMR methods. The highly substituted cyclohexenes were synthesized with a Diels-Alder reaction involving 2,3-dimethyl-1,4 butadiene and an analog of trans-cinnamic acid, bearing various substituents on the phenyl ring. NMR spectra of the Diels Alder adducts were obtained on a Varian HA-100 in $CDCl_3$ or DMSO solutions. The two ABM_2 spin systems were then subjected to a computer analysis using the perturbation approach, and the splitting constants were applied to the Karplus equation.

MODIFICATION OF FATTY ACID METABOLISM IN DROSOPHILA MELANOGASTER BY DIETARY CARBOHYDRATE AND LIPID, T. J. Perille and B. W. Geer, Knox College, Galesburg, 61401. Dietary lipid represses the tissue levels of glucose-6-phosphate dehydrogenase, 6-phosphogluconate dehydrogenase, malic enzyme, and NADP-isocitrate dehydrogenase in larvae. By feeding fatty acids of different carbon lengths, it was found that fatty acids of 14-carbons or greater in length repress the tissue levels of the NADP-enzymes. A mixture of saturated and unsaturated fatty acids was most effective. The tissue fatty acid content was significantly altered by the dietary fatty acids. Also, supplementation of a fat-free diet with sucrose increased the amount of palmitoleic acid relative to the amount of palmitic acid in the larvae.

NUCLEOPHILIC AROMATIC SUBSTITUTION PROMOTED BY COBALTIC TRIFLUOROACETATE, Gerald Hage and Michael Kurz, Ill. State Univ., Normal, 61761.

Recently it has been shown that nucleophilic aromatic substitution on non-activated aromatics can be performed with the strong electron-transfer metal salt oxidant cobaltic trifluoroacetate. This reaction, which proceeds by way of an electron transfer process, involved eventual transfer of the metal ligand moiety onto the aromatic (eq. 1). We are undertaking a study to extend the scope of this novel process by attempting to substitute other nucleophiles (e.g., Cl^-, Br^-, CN^-) onto aromatics of varying π-electron densities in the presence of cobaltic trifluoroacetate. High yields of chlorobenzene were obtained from benzene using this process. The mechanism and scope of this type of aromatic substitution will be discussed.

$$ArH \xrightarrow[-Co^{+2}]{Co^{+3}} ArH^{\bullet +} \xrightarrow{CF_3CO_2^-} Ar\overset{H}{\underset{O_2CCF_3}{\bullet}} \xrightarrow[-Co^{+2}]{Co^{+3}} ArO\overset{O}{\overset{\|}{C}}CH_3 + H^+ \quad (1)$$

SULFUR DIOXIDE REMOVAL WITH AMMONIA AT THE PPM LEVEL. Brian Zale and Robert C. Duty, Chem. Dept., Illinois State Univ., Normal, IL. 61761.

Teflon permeation tubes of liquid sulfur dioxide and liquid ammonia have been constructed which are used to generate two separate streams of sulfur dioxide and ammonia, respectively, at approximately 100 ppm. These two streams of gases in moist air (approximately 100 ml/min/air stream) are mixed in a verticle chamber (50 cm x 2.4 cm). The removal of sulfur dioxide by the ammonia has been successful to the 95% level. Residence time in the all-glass apparatus is less than 3 minutes as calculated from dead volume space and flow rate. Sulfur dioxide levels are established by a colorimetric method and ammonia is trapped in a standardized HCl solution. Experimental apparatus and procedure will be discussed along with the experimental results.

THERMAL DECOMPOSITION OF NITROCELLULOSE-BASED PROPELLANTS. Paul J. Zack and J. E. House, Jr., Illinois State University, Normal, Illinois 61761. Differential scanning calorimetry has been used to study the thermal decomposition of nitrocellulose-based propellants at atmospheric pressure. Five different propellants gave heats of decomposition of about 500 cal/gram. Double base propellants containing about 10% nitroglycerin appear to have about the same heat of decomposition. The heat of decomposition at atmospheric pressure is only about half that obtained by burning the propellants under conditions of use at several thousand atmospheres of pressure. Application of thermal decomposition to problems of analysis and identification are discussed.

KETO-ENOL EQUILIBRIUM MEASUREMENTS OF BENZOYL ACETYL CHLORIDE. Michael Becker and Robert C. Duty, Chemistry Dept., Illinois State University, Normal, IL. 61761.

Keto-enol equilibrium results have been established for a new compound belonging to the β-keto acid chloride series. The benzoyl acetyl chloride compound has been successfully isolated and the keto-enol equilibrium concentrations at room temperature have been determined in deuterated chloroform on an Hitashi R-20 NMR instrument. These results will be compared with other β-keto functional groups, e.g., benzoyl acetic acid, ethyl benzoyl acetate, acetyl acetic acid and acetoacetic ester. Experimental conditions along with inductive effect influences on keto-enol equilibria will be discussed.

ENVIRONMENTAL SCIENCE

PHYTOPLANKTON TAXONOMY, DENSITY, AND WATER QUALITY INDICES FOR TOLLWAY BORROW PIT PONDS, Louis Lipsey, Jr., Northern Illinois University, DeKalb, IL 60115. The identification of phytoplankton and the calculation of algae density were determined to compare the water quality of ten different tollway ponds. Sampling was accomplished utilizing a 1-liter Kemmerer sampling device. Phytoplankton were enumerated using a Sedgwick-Rafter counting cell. Seventy-two algal species were identified and the calculations of algae indices showed the ponds to be quite productive. Data analyses revealed unique properties for each pond studied, as oligotrophic species were intermixed with eutrophic species, indicating that sudden environmental changes in the ponds may vary their community structure.

ALGAL TASTE AND ODOR PROBLEMS IN SOME SOUTHERN ILLINOIS RESERVOIRS, Mary Piper and Robert C. Haynes, Sangamon State University, 62703. The relationship of algal populations to reported tastes and odors in water supplies from some southern Illinois reservoirs was investigated during the summer of 1975. Algal samples were obtained from Marion and Rend lakes at two week intervals. Other reservoirs were sampled when tastes and odors were reported. It was found that taste and odor occurence corresponded to fluctuations in the population of Anabaena planktonica in Marion Lake. Known taste and odor algae were also identified for Vandalia and Patoka reservoirs when problems occured.

OBSERVATIONS ON OPERCULAR BEATS IN THE GREEN SUNFISH(LEPOMIS CYANELLUS) UNDER SOCIAL AND OXYGEN STRESS, Paul E. Crosser and David A. White, Western Illinois University, Macomb, 61455. Opercular beats were observed four times for one minute each within a five minute time period. Observations were made on a fish in both a community tank and respirometer utilizing a D.O. electrode. A linear correlation between an increase in opercular beats and decreasing D,O. was observed. A similar increase in opercular beats was observed in a sub-dominant fish when the dominant fish approached. The opercular beats of the fish in an oxygen stress situation were more forceful. We conclude that a similar stress reaction can be induced by both physical and social stress.

ACUTE TOXICITY OF POTASSIUM TO THE FINGERNAIL CLAM, MUSCULIUM TRANSVERSUM, Richard E. Sparks and Kevin B. Anderson, Illinois Natural History Survey, Havana, 62644. The 48, 72, 96, and 120 hour LC50's for adult clams (shell length greater than 4 mm) were 518, 255, 185, 168 p.p.m. K^+ respectively. The 48, 72, 96, 120, 168, 240, and 264 hour LC50's for juvenile clams (shell length less than 4 mm) were 2700, 1380, 530, 435, 300, 270, and 250 p.p.m. K^+ respectively. Criterion for death of adults was gaping (dead clams gaped wider than live clams which gaped and recovered), for juveniles, criteria were absence of heartbeat and gaping. Adults appear to be 3-5 times more sensitive to potassium than juveniles.

COMPARISON OF MERCURY LEVELS IN FISH FROM SEVERAL ILLINOIS LAKES, Kenneth E. Smith, Illinois Natural History Survey, Urbana, 61801. Total mercury analysis of over five hundred fish covering eleven species from six central Illinois lakes; Lakes Sangchris, Otter, Decatur, Shelbyville Carlyle and Rend, were completed since the beginning of the study. The results showed changes in mercury concentrations over the sampling period of three years, differences in the various lakes, and variations between the species sampled. Also to be discussed is a possible mechanism of mercury concentrations in the large reservoirs.

ILLINOIS WATERWAY TOXICITY INDICES: 1972-1974, K. S. Lubinski and R. E. Sparks, Dept. of Biology and Center for Environmental Studies, Virginia Polytechnic Institute and State University, Blacksburg, Va., 24061, and Illinois Natural History Survey, Havana, Il., 62644. Illinois Environmental Protection Agency data on the concentrations of ammonia nitrogen, cyanide, copper, MBAS, lead, phenol and zinc at 20 stations on the Illinois Waterway were compiled into mean and maximum toxicity indices for the years 1972-1974. Toxicant concentrations were expressed as fractions of their LC50 concentrations to bluegills, Lepomis macrochirus, and summed to yield the toxicity indices of the waterway. Ammonia nitrogen, MBAS, and cyanide were the major contributors to the toxicity of the waterway, but to assess their individual and combined effects on aquatic life, the toxic forms of these substances (unionized ammonia, LAS, HCN) must be measured and reported.

THE REPRODUCTIVE BEHAVIOR OF THE ASIAN CICHLIDS AND THE INTERSPECIFIC CLEANING SYMBIOSIS BETWEEN THEM, Jack A. Ward and George B. Kuzo, Illinois State University, Normal, 61761. Three 16 mm films produced at ISU and currently duplicated and distributed by Encyclopaedia Cinematographica of Germany (North American Repository - Penn. State) will be shown. Two films detail the general reproductive biology and behavior of the Asian cichlid fishes, Etroplus maculatus and E. suratensis. The final film details a true cleaning symbiosis that has evolved between the species - the symbiosis is ironic since at one time in the life cycle of each the species are prey and predator rather than symbionts.

METHYL MERCURY CHLORIDE UPTAKE AND ELIMINATION IN THE BLOODWORM, GLYCERA DIBRANCHIATA, Denis M. Medeiros, Robert L. Preston, and Larry L. Cadwell, Illinois State University, Normal, 61761. Uptake of CH_3HgCl-203 by body wall sections of Glycera exposed to 10ppb is usually linear for 1 to 10 minutes and proceeds more slowly thereafter. Efflux of CH_3HgCl from exposed tissue is low when using sea water as an efflux medium, but much higher when using a 40mM cysteine in sea water efflux medium. More than 3/4 of the CH_3HgCl is released by the tissues in a cysteine efflux medium. Whole worms exposed to 10ppb CH_3HgCl for 4 days had a rapid uptake in the first 2 hours of exposure with a leveling off thereafter. This evidence from the short and long term exposure studies indicate that uptake of CH_3HgCl is composed of two phases, a rapid sulfydryl dependent phase followed by a much slower phase.

ACUTE RESIDUAL CHLORINE TOXICITY OF BLUEGILL AND CHANNEL CATFISH, Donald Roseboom and Dorothy Richey, Illinois State Water Survey, Peoria, 61601. 96-hour chlorine bioassays were run on Bluegill and Channel Catfish with a modified Mount and Brungs proportional dilutor. 96-hour TL_M's for Bluegill and Catfish were 0.33 mg/l and 0.09 mg/l respectively, and the environmental effects of water temperature and fish weight were quantified through linear regression analyses. The product of the 96-hour TL_M and the 0.1 Illinois safety factor places the allowable residual chlorine at the limit of detection for the amperometric titrator and essentially means no detectable chlorine is allowed in Illinois waters.

PARASITES OF CHANNEL CATFISH IN ILLINOIS HATCHERIES, Charles Dale Meryman, Eastern Illinois University, Charleston, 61920. Ninety Ictalurus punctatus were trapped during September 1973 through April 1974 at three hatcheries located at Worden, Centralia and Kinmundy, Illinois. All were examined for parasites and 87 were parasitized. The trematodes Azygia angusticauda and Neascus sp. were found in the intestinal system and Cleidodiscus floridanus and Dactylogyrus sp. were attached to the gills. Five cestode genera, Bothriocephalus sp., Corallobothrium giganteum, Eubothrium sp., Haplobothrium sp. and Proteocephalus ambloplitis were present. Protozoans, Costia sp., Myxobolus sp., Scyphidia macropodia and Trichodina discoidea and one kind of glochidium and one nematode, Rhabdochona were found. Three non-parasitic diseases were noted, Anemia, Dietary gill disease and Lipoid degeneration of the liver and a bacterial infection, Chondrococcus columnaris.

SELECTIVE FEEDING PREFERENCES OF THE AMPHIPOD (HYALELLA AZTECA) ON NATURAL AND ARTIFICIAL SUBSTRATES, Thomas H. Allen and David A. White, Western Illinois University, Macomb, 61455. A selective feeding study was undertaken to determine food preferences of the amphipod, Hyalella azteca at air temperatures of 1.66°C, 23°C, and 31°C. Selectivity offered the organisms consisted of sterile and natural 1 cm. diameter leaf discs of Acer saccharinum L., Quercus imbricaria Michx, Quercus alba L., Populus deltoides, Marsh, and Zea maize L., and artificial substrate discs of cardboard, plastic, glossy magazine paper, and paper towel. Preliminary results indicate that the descending order of preference is: Populus deltoides, Zea maize, Quercus imbricaria, Acer saccharinum, Quercus alba, glossy magazine paper, cardboard, paper towel, and plastic.

GEOLOGY-GEOGRAPHY

ILLINOIAN TILL ANOMALIES IN WEST-CENTRAL ILLINOIS, Michael Kearney, Kenneth Laurie, and Dennis Lubbs; Western Illinois University, Macomb, Illinois 61455.

Grain size analyses and X-ray diffraction of carbonate and clay minerals of Illinoian-age till exposures around Macomb, Illinois, has revealed the existence of a new till inconsistent with current interpretations of Illinoian events for West-Central Illinois. A model, suggesting the channelization of surges from a stationary Liman ice-front up bedrock vallies, is proposed.

A NOTE ON THE RATE OF SOIL DEVELOPMENT AND ITS RELATIONSHIP TO THE PLEISTOCENE RECORD, Fred Caspall and Bruce Fitzgerald, Western Illinois University, Macomb, 61455. Young soils of known age were studied to determine the rate of soil development in unconsolidated earth materials. Significant destruction of carbonate minerals and accumulation of organic matter was detected in soils of less than thirty years in age. Such rapid soil development suggests that some of the paleosols reported from Wisconsinan age deposits could result from less tnan one hundred years of weathering. Caution is suggested when weakly developed paleosols are used as stratigraphic markers.

ORIGIN OF ROCK GLACIER IN THE COLORADO FRONT RANGE. Gary Wallace, Eastern Illinois University, Charleston, 61920. Considerable field evidence exists; such as, ridge and furrow patterns, steep fronts, lichen growth, and plane table surveys to show that rock glaciers have and are presently moving. Arapaho rock glacier occupies a cirque. A buried ice glacier lies beneath the upvalley one-third of this rock glacier. Organic material from the shear planes yielded an age of 1000 years ± 90 B.P. The down valley two-thirds of the rock glacier contains interstitial ice. It owes its origin and movement to a buried ice glacier and to interstitial ice. Buried ice glaciers are helpful but not necessary to the origin of rock glaciers. Interstitial ice alone is attributed to the origin and movement of rock glaciers originating on valley sides.

PRESERVATIONAL FORMS OF BLOBS FROM THE PENNSYLVANIAN ESSEX FAUNA IN ILLINOIS, George S. Nadasdy, Bradley University, Peoria, 61606 Structures informally termed "blobs," common in concretions of the Pennsylvanian Essex Fauna are believed to be coelenterate medusae catastrophically buried during seasonal storm surges in an interdistributary bay environment. Collections were mainly from naturally opened concretions weathered from strip mine spoil heaps. The forms of the "blobs" correspond well with the forms assumed by Recent medusae imbedded in marine sediments in such areas as the North Sea. The different forms taken by "blobs" probably reflect a variety of modes of preservation rather than significant taxonomic diversity.

BRIEF REVIEW OF PALEOENVIRONMENTS OF THE ILLINOIS BASIN. Richard L. Leary, Illinois State Museum, Springfield, IL 62706. During the Pennsylvanian Period, a variety of environments existed in and around the Illinois Basin. These are recognized on the basis of both floral differences and lithologic variations. Extensive lowlands occupied large areas of the Basin during much of the Pennsylvanian. Major valley systems developed on Mississippian carbonates prior to Pennsylvanian sedimentation. During the Pennsylvanian, deltas, coastal marshes, channels and other environments existed within the lowlands. On the margins of the Basin were both moist and dry upland areas. Valleys, channels, sinkholes and other depressions developed on pre-Pennsylvanian strata exposed on the Basin margin. Plant fossils are known from examples of each of the topographic settings. It is important that correlations between paleoenvironments determined on paleobotanical grounds and those based upon geological factors be understood.

PRELIMINARY GEOPHYSICAL STUDIES, BEDROCK TOPOGRAPHY, MCDONOUGH CO. ILLINOIS, T. D. Edmondson, P. L. Oberlander, and J. S. Klasner, Geol. Dept. Western Illinois University 61455. Close correspondence in density between some bedrock and drift in west central Illinois may prohibit detection of buried bedrock valleys. Studies by students at W. I. U., however, indicate that, generally, gravity data can be used to locate the position of buried valleys in western Illinois. Seismic refraction gives details of buried valley configuration. Analysis of presently available gravity data, along with supplementary gravity data and select seismic refraction data should provide a useful tool for refining current bedrock topography maps. Such geophysical technique should prove a valuable adjunct in assessing both ground water potential and pollution in this area.

FOSSIL FIORDS, VICTORIA LAND, ANTARCTICA, Peter N. Webb, and John H. Wrenn, Northern Illinois University, DeKalb, 60115. Three major valley systems, all about 80 km long, have been carved through the Transantarctic Mountains by glaciers moving from the east Antarctic ice cap to the Ross Sea. Early workers determined a purely terrestrial history for these valleys and their sediments and suggest that this landscape was produced during the Quaternary. Recent stratigraphic and micropaleontological investigations, aided by deep drilling, indicates that these valleys have a long glacio-marine history, extending back at least to the Miocene. Major Late Cenozoic tectonic movements elevated the coastal Transantarctic Mountain Range. This produced a marine regression and resulted in the totally terrestrial environment of today.

A SUMMARY OF METEORITES RECOVERED IN ILLINOIS. Paul P. Sipiera, Aurora College, Aurora, IL 60507.

Mineralogical and chemical analyses of meteorites provide data to formulate and support theories for the origin of the earth and solar system. This science of meteoritics is such that the next meteorite discovery may contain evidence to reaffirm or contradict existing theories. Since 1927, a total of seven meteorites have been found in Illinois. Although Illinois cannot boast the largest number of meteorites discovered, it can account for some of the most interesting. The possibility of finding additional meteorites in the state is good, provided recovery efforts are expanded.

A NEW MEMBER OF THE BANNER FORMATION, Dennis Lubbs, Kenneth Laurie, and Michael Kearney, Western Illinois University, Macomb, IL 61455.

Recent laboratory research, using pipette and x-ray diffraction techniques, has delimited a new, extensive member of the Banner Formation. This member consists of leached to slightly calcareous, blue-gray to red-brown lacustrine silts of mid to late Kansan age. The Yarmouth Soil is developed in the upper portion and is overlain by sands of the Glasford Formation.

LATE WISCONSINAN CLIMATIC FLUCTUATION AND LOESS DEPOSITION, Joseph M. Moran, University of Illinois, Urbana, 61801. Glacial-non-glacial climatic shifts exhibit an episodic or square-wave behavior, while the response of glacial ice volume is in the form of a modified saw-tooth wave. If this model is valid, peak Laurentide meltwater discharge and sediment yield occurred several thousand years after the last major Wisconsinan climatic shift from dominantly glacial to non-glacial regimes. The concurrent lag in flood plain deflation and loess deposition is verified by evidence reported from loess deposits in Iowa. It is further demonstrated that Midwestern loess deposition was a seasonal phenomenon that can be explained by a March-like surface streamline pattern.

THE OCCURRENCE OF VIVIANITE IN A SUB-SANGAMON PROFILE, IPAVA, ILLINOIS, Willard McCracken and Dennis Lubbs, Western Illinois University, Macomb, 61455. The occurrence of nodular concretions and aggregates of a blue mineral in a sub-Sangamon clayey silt deposit of Pleistocene age was investigated in the study area near Ipava, Illinois. Identification of vivianite was confirmed from X-ray diffraction analysis, phosphate and iron peaks from X-ray energy spectrometry, and optical data. Scanning electron micrographs of collected samples reveal that the nodular aggregates of vivianite consist of 1 - 5 micron euhedral crystals. The scanning electron micrographs show that the vivianite crystals are authigenic and insitu. The association of peaty wood with the vivianite nodules suggests a reducing environment, interpreted as a lake bog.

An Evaluation of the Water Resources of Kane County, Illinois. Brian S. Sebastian and Paul P. Sipiera, Aurora College, Aurora IL 60507.

Water resource management is becoming extremely important as urban sprawl continues to encroach upon the remaining available land. Kane County, Illinois is an area of increasing urbanization, and is dependent upon subsurface water for both consumption and sanitation needs. In the present study a correlation of precipitation, recharge and pumping data indicates a general lowering of the water table. This fact, combined with increases in population and continued industrial growth, suggests a serious threat of future water shortage for the area.

ELECTRICAL RESISTIVITY SOUNDING AS A MEANS OF DETERMINING BEDROCK DEPTHS IN WESTERN ILLINOIS, Christopher Schmidt and Janet Docka, Knox College, Galesburg, 61401. In areas of western Illinois where knowledge of bedrock depths is lacking because of insufficient well log data, the depth to bedrock may be determined by electrical resistivity or seismic refraction techniques. The Barnes Layer Method of interpreting resistivity data appears to be the most accurate for depths up to 200 feet. Of 12 bedrock depths determined by this method, 5 were within 10% of the depths determined by seismic refraction at the same locations and the remainder were within 50% of the seismically determined depths. This suggests that, where cost prohibits the use of seismic equipment, careful analysis of resistivity soundings can provide a reasonably accurate alternative to determination of bedrock depths in western Illinois.

GRAVITY MODELING OF A DRIFT FILLED BEDROCK VALLEY IN WESTERN ILLINOIS, Christopher Schmidt and Carol Savidge, Knox College, Galesburg, 61401. In those areas of western Illinois where the underlying bedrock is predominantly limestone the configuration of preglacial, drift-filled bedrock valleys is amenable to gravity modeling. An east-west gravity profile derived from 26 stations along a 3-mile line in northeastern Hancock County indicates the presence of two negative Bouger anomalies with magnitudes of approximately 2 milligals. Two-dimensional modeling of the bedrock surface indicates the presence of a divided bedrock valley with a relief of slightly over 100 feet. The fact that the bedrock surface map of Illinois (Horberg, 1957) indicates a single undivided drift-filled valley with over 200 feet of relief at this location probably reflects the lack of sufficient well log data in this area.

IS THERE A SUBCULTURE OF VIOLENCE IN THE SOUTH?, Lawrence T. Lewis, Western Illinois University, Macomb, Ill. 61455. One of the most controversial explanations of the abnormal homicide rates in the South has been the theory of a regional subculture of violence. Full confirmation of the theory at this time cannot be made because of the lack of appropriate data. This study, however, is a preliminary attempt,using historical, statistical and attitudinal evidence, at providing supportive documentation for the theory. Among the findings about the South which are consistent with a regional culture of violence are: 1) violence and firearm ownership have a long history; 2) violence pervades all subpopulation levels; 3) although poverty and related factors are important etiologically they do not fully explain the high rate of violence; 4) data from opinion polls reveal that the South is more prone to accept violent solutions to problems than is the rest of the nation.

Galesburg: Energy Consumed by the Community in 1973 and Suggestions for Reducing the Amount of Energy Consumed. D.M. Moore, Knox College, Galesburg, IL 61401.

The community of Galesburg, Il., consumed 4,170 billion kcal of energy in 1973. Partial implementation of the suggestions we make here with partial success could easily save 665 billion kcal or about 16 percent. Realizing these savings is a complex problem the solution to which is not technological but social and psychological. Economically, our style of life is characterized by a reliance on growth, everyone gaining more and more goods, wealth and services each year. There is ample evidence, both in scholarly works and cultural documents, to suggest that changing to less materialistic values and actions is accompanied by a number of benefits. In our specific case, we conclude that efforts to save energy would result in a more peaceful, quieter city characterized by a vigorous sense of community.

METEOROLOGY-CLIMATOLOGY

AN EFFECTIVE INDEX FOR DROUGHT DETECTION UTILIZED IN THE CONCHOS RIVER BASIN DROUGHT, Redmond R. Clark, Asst. Professor, Dept. of Geography, Elmhurst College, Elmhurst, 60126. In a recent Water Supply Paper of the U.S.G.S., Sauer (1972) considered land use, surface and ground water use, precipitation intensity, and precipitation duration as possible causes of the extreme lowflows of the Conchos River during the period 1962-1968. As a result of these analyses, Sauer concluded that the lowflows were the result of decreased annual precipitation and precipitation intensity. It is apparent that annual precipitation is not linearly related to annual streamflow, but is related thru some form of the hydrologic equation: Streamflow = Precipitation - Evapotranspiration $\pm$ Change in Storage. An analysis using the hydrologic equation indicated that the lowflows of the Conchos River may have been due to the distributional aspects of precipitation versus environmental moisture demand.

EFFECTS OF CLIMATE ON THE SITE OF THE AIR FORCE ACADEMY, COLORADO, Walter N. Duffett, Eastern Illinois University, Charleston, 61920. There are both positive and negative effects of climatic elements on the site, structures and personnel at the Air Force Academy, Colorado. A ten-year period of empirical observations and collected data are used to evaluate the site climatically as a training and educational environment. A combination of high winds, heavy snowfall and summer lightening strikes are negative aspects of this location. Invigorating summer night temperatures, low relative humidity and a high percentage of clear skies somewhat offset these negative attributes. A somewhat debatable point of acclimatization to a site elevation of 7,200 feet above sealevel complicates the situation slightly. In conclusion, the selection of the site for the AF Academy was a poor choice from a climatic standpoint, but other factors offset the climate.

SHACKHAM BROOK REVISITED: ACTUAL EVAPOTRANSPIRATION AND TREE GROWTH, Redmond R. Clark, Asst. Professor, Dept. of Geography, Elmhurst College, Elmhurst, 60126. Richard Phipps (1972) attempted to establish an association between tree growth and climate extremes. Climatic extremes were expressed through precipitation and runoff maximum and minimum years. Through the use of a non-parametric statistical technique, Phipps demonstrated a strong association between growth extremes and "climate" extremes. Because of the intimate association between growth and water availability, actual evapotranspiration extremes were applied to tree growth extremes. The results indicated that actual evapotranspiration alone was more effective than both runoff and precipitation in accounting for growth extreme variations.

HISTOCHEMICAL STUDY OF THE EFFECT OF HBAg ON NICOTIANA SYLVESTRIS. J. Moldenhauer and A. S. Dhaliwal, Loyola University, Chicago, Illinois 60626. Dhaliwal, et al., in 1975 reported that HBAg caused stunting in N. sylvestris. Present study was initiated to assess if HBAg induced any histochemical changes in N. sylvestris. The leaves of about 3 to 5 week old plants were inoculated with HBAg both by rubbing and intravascular injections. Inoculated and uninoculated leaves were processed for light microscopy at 24 hr intervals by fixing in FAA and staining with Fuelgen's stain and special hepatitis stain (Huang's method). Preliminary results showed the presence of hepatitis antigen in epidermal cells until 48 hrs. Nucleic acid content remained the same in both HBAg treated plants and controls. However, some cytopathic changes were observed in palisade tissue of the treated plants.

PENETRATION OF RHIZOPUS OLIGOSPORUS INTO SOYBEANS DURING TEMPEH PRODUCTION. Alan M. Jurus and Walter J. Sundberg, Department of Botany, Southern Illinois University, Carbondale, Il 62901. Histological observations demonstrated that during tempeh production hyphae of Rhizopus oligosporus Saito penetrated the soybean cotyledons an average of once every 1300 μm^2 and once every 1010 μm^2 on the curved (outer) and flat (inner) surfaces respectively. They infiltrated to a depth of 742 μm or about 25% of the average cotyledon's width. This previously unreported degree of penetration offers partial explanation for the rapid changes that occur in the soybeans during the tempeh fermentation process.

EFFICACY OF AN INFECTIOUS BOVINE RHINOTRACHEITIS VACCINE IN CALVES, Emilie Zehr, I. L. Shechmeister, and L. E. Strack, Southern Illinois University, Carbondale, 62901. A formalin-killed alginate adjuvant infectious bovine rhinotracheitis (IBR) virus vaccine was prepared and injected intramuscularly into two to six month old calves. Sera were collected and assayed for anti-IBR antibodies before and after vaccination. Assay methods included serum neutralization and complement fixation tests. A significant increase in antibody titre was obtained.

IMMUNOLOGIC PHENOMENA IN THE NATURAL HISTORY OF CANCER, Israel Davidsohn, Rush Medical College and Mount Sinai Hospital Medical Center, Chicago, 60608. Conquest of cancer is a frequent topic in the press and on the air. The steps in the conquest of cancer are: 1) Nature of the disease: abnormal destructive growth; 2) Cause: variety of causes; only some known; 3) Early diagnosis: before growth has spread beyond the site of origin; 4) Predisposition: advanced age, though occurring at all ages; 5) Prevention: the most desirable aim; 6) cure if prevention not possible; 7) Treatment (living with the disease if prevention and cure are not possible). Results already achieved hold promise of success especially of early diagnosis than any other attempts thus far. Results of our immunologic studies will be presented.

THE EFFECTS ON RATS TREATED WITH CULTURES OF PULLULARIA PULLULANS WITH AND WITHOUT THE ADDITION OF ITS PIGMENT. Charles F. Lange, Emanuel Merdinger, and Assen Toshkov, Loyola University Stritch School of Medicine, Maywood, 60153 and Institute of Microbiology, Bulgarian Academy of Sciences.

Dimethylformamide solutions containing 0.0125% pigment extracted from Pullularia pullulans were injected in several groups of rats intravenously, intraarticularly and in the paws. After 15 days 66% of the intravenously treated rats and 30% of the intraarticularly treated rats developed orchitis. After 45 days 99% of both groups developed orchitis which measured from 9 to 12 mm. Not a single animal of the third group paw injected showed orchitis at 15 days and were unfortunately discarded.

ULTRASTRUCTURAL STUDIES OF HYMENOLEPIS DIMINUTA, PARASITE TAPEWORM IN THE INTESTINE OF RAT, Pattle P.T. Pun, David R. Jacobson and Ronald P. Babich, Dept. of Biology, Wheaton College, Wheaton, IL. 60187. Sprague-Dawley strain of rat, Rattus norvegicus was infected with the intestinal tapeworm, Hymenolepis diminuta. The rat was sacrificed with an overdose of ether. Intestines from the infected rat and the tapeworms were fixed in glutaraldehyde and osmium tetroxide, dehydrated with alcohol and propylene oxide and embedded in epon. Sections were examined with an RCA-3F electron microscope. Electron micrographs of intestine from infected rat were compared to normal rat. The ultrastructure of Hymenolepis diminuta was examined.

THE EFFECT OF SODIUM CHLORIDE AND CARBOHYDRATES ON THE KANAGAWA PHENOMENON, Mike Zielinski and Riaz-ul Haque, University of Illinois, Med. Ctr., 835 S. Wolcott, Chicago, Illinois 60680. The Kanagawa Phenomenon, an in vitro correlate of pathogenicity for strains of Vibrio parahemolyticus, is expressed on Wagatsuma's medium. Determinants of colony size and hemolytic zone size were studied. A medium consisting of 2% peptone agar with increasing NaCl and carbohydrate concentrations was utilized for this study. A ratio based on colony diameter divided by hemolytic zone diameter was used to correlate the results found on the different media tested. Sodium chloride affected colony size whereas carbohydrates affected hemolytic zone size. The growth of both Kanagawa positive and Kanagawa negative strains appeared to be inhibited by the addition of NaCl. Carbohydrates appeared to enhance the production of hemolysin for both strains, especially the Kanagawa negative.

EXTRACELLULAR HYALURONIDASE ACTIVITY IN BACTEROIDES FRAGILIS. Walter Rudek and Riaz-ul Haque, University of Illinois at the Medical Center, Chicago, 60680. The extracellular production of a hydrolase has been studied in B. fragilis. The enzyme is a mucopolysaccharidase that hydrolyzes hyaluronic acid. Brain heart infusion broth supplemented with yeast extract was the best medium for the demonstration of the enzyme in crude filtrates. The optimum pH range of the enzyme was 8.0 to 8.8. The enzyme is secreted throughout log phase with a slight decrease activity during the stationary phase. Histological sections of subdermal tissue following injections of the crude filtrate show diffuse collagen staining. It is likely that this enzyme may aid in the spreading of the lesion that is seen in many infections by Bacteroides.

EPIDEMIOLOGY OF SERRATIA MARCESCENS IN A HOSPITAL, Frederick Miller, Elinor Roemisch and Frank E. Kocka, University of Chicago, Chicago, 60637. Serratia marcescens are frequently seen as hospital acquired organisms in patients with urinary tract catheters. When acquired in the hospital these organisms are frequently resistant to most antibiotics. It is therefore important that hospital reservoirs of this organism be found and eliminated. To achieve this goal, S. marcescens isolated from patient and environmental sources were grouped by methods including antibiotic susceptibility patterns, biochemical patterns, serotyping with somatic antigen and bacteriocin typing. In the past two years, the resistance to gentamicin has changed from 0 to 50%. Hospital environmental reservoirs may have played an important role in this transition.

RAPID IDENTIFICATION OF GROUP B STREPTOCOCCI, M. Anwer Hidayatullah, Frank E. Kocka and Josephine A. Morello, University of Chicago, Chicago, 60637. Group B streptococci are the second most frequent cause of neonatal septicemia and meningitis. Therefore a method for rapid identification of this organism is needed in clinical laboratories. Groups of beta hemolytic streptococci were tested by four methods which were compared for speed, sensitivity and ease of performance. These tests included the CAMP reaction, rapid hippurate hydrolysis, anaerobic production of pigment and counter current immunoelectrophoresis. Results with 60 group B isolates indicated that for routine use the CAMP reaction fit all of the above criteria. Results were often available within 4 hours. In the adult population, Group B streptococci were most commonly isolated from female urogenital specimens and wound cultures.

ULTRASTRUCTURAL LOCALIZATION OF PAS POSITIVE SUBSTANCES WITH THIOSEMICARBAZIDE IN DIPLODIA MAYDIS: EVALUATION OF THREE FIXATIVES FOR PA:TSC:OS REACTION. Judith A. Murphy, Mary R. Thompson, and A.J. Pappelis. Southern Illinois University, Carbondale, IL 62901. Glutaraldehyde, formaldehyde and paraformaldehyde were used in conjunction with PA, TSC, and Os to localize polysaccharides in D. maydis. There are at least three distinct types of storage areas in the cell, one of which is PAS+. PAS+ material was also found in the lomosomes and in the septal regions with none found in the nucleus, mitochondria, ribosomes or in Woronin bodies. In considering cellular preservation and the least amount of non specific reaction, paraformaldehyde seems the best fixative for use with PA:TSC:Os for PAS+ localization in D. maydis.

EFFECT OF POLYMYXIN B ON OUTER-MEMBRANE COMPONENTS OF SERRATIA MARCESCENS, David A. Brown and Joseph C. Tsang, Illinois State University, Normal, Illinois 61761. Although polymyxin B (PB) exerts a nonlethal action on the outer-membrane of gram(-) bacteria, the exact molecular basis of this interaction is less than clear. In this study, we used immunoelectrophoresis (IE) and polyacrylamide gel electrophoresis(PGE) to study the changes of the outer-membrane components after treatment with PB. Outer-membranes were isolated from lysozyme-EDTA treated cells by the Osborn method from a a PB resistant and a PB sensitive strain of S. marcescens. After PB treatments, it was shown by PGE that a 23,000-27,000 dalton component decreased in intensity while a 200,-000 daltons component increased significantly in outer-membranes of both strains. By IE, the neutral lipopolysaccharide (LPS) bands were shown to disappear when sensitive cells were in vivo treated with PB. Results of this study showed that PB exerted degradative actions on both the LPS and protein components in the outer-membrane.

EFFECTS OF POLYMYXIN B ON THE INTEGRITY AND LOCALIZATION OF LIPOPOLYSACCHARIDE IN THE OUTER-MEMBRANE OF SERRATIA MARCESCENS, D. A. Weber, M. J. Nadakavukaren and J. C. Tsang. Illinois State University, Normal 61761. Although the morphology of gram(-) bacteria is altered through the interaction of polymyxin B (PB) with lipopolysaccharide (LPS) components of the outer-membrane (OM), the exact nature of the interaction is not known. To elucidate the effect on the morphology, outer-membranes from resistant and sensitive cells were studied before and after treatment with PB. Electron microscopic results showed that the untreated OM from both types of cells appeared spheroidal with a smooth periphery. After the PB treatment, the OM of the resistant strain was similar to the untreated OM. However, the OM of the sensitive strain appeared disrupted with a loss of its integrity. In order to determine if LPS is the site of disruption by PB, treated and untreated OM from the sensitive cells were stained with $AgNO_3$-methenamine, a polysaccharide localization reagent.

ISOLATION OF BACTERIA CAPABLE OF GROWTH UNDER ALKALINE CONDITIONS, Lawrence N. Schmidt and Betty J. Cole, Illinois State University, Normal, 61761. Samples from alkaline springs and soils in Illinois and California were used for the selective isolation of bacterial strains capable of growth at pH's ranging as high as pH 11. Samples from alkaline environments served as inocula for a series of enrichment cultures in tryptic soy broth at pH 9.5, 10.6 and 11.0 incubated at 23, 29, 37 and 55 C. Pure cultures were obtained from the enrichment cultures via serial single colony isolations using pH 10.6 tryptic soy agar. pH gradient plates were used to select those isolates with optimum growth at pH 8 or above. These isolates were further characterized on the basis of their cultural characteristics, morphology, gram reaction, motility and selected biochemical properties. The optimum growth of these isolates at high alkaline pH's is the basis for considering them as alkalinophilic bacteria.

STAPHYLOCOCCAL MITOGENS. Sheng-Hao Lee and Riaz-ul Haque. University of Illinois at the Medical Center, Chicago, Illinois 60680 Culture filtrates of the 146P strain of Staphylococcus aureus when analyzed for mitogenic activity using ^3H-thymidine incorporation by rabbit spleen cells were found to be highly mitogenic. Fractionation of the filtrate using various procedures revealed the presence of multiple mitogenic components. The major mitogenic component(s) however precipitated with acetone, alcohol, chloroform, ether and genetron, were electrophoretically immobile, non-dialyzable and heat stable (100° C, 30 min). During the fractionation procedures the major mitogenic component(s) usually partitioned together with lipase, egg yolk factor, esterase, staphylokinase, deoxyribonuclease, hyaluronidase, phosphatase, lysozyme, and alpha and delta toxins. Purified alpha and delta toxins were also found to be strong mitogenic agents.

JOINT PHYSICS SESSION WITH THE ILLINOIS SECTION OF THE AMERICAN ASSOCIATION OF PHYSICS TEACHERS

A UNIT OF "NUCLEAR ENERGY" IN HIGH SCHOOL PHYSICS AND/OR CHEMISTRY, Stephen A. Mills, Roseville, Illinois 61473.

Content of Unit:
1. Fission process
2. Fusion process
3. Man made elements
4. Making isotopes radioactive
5. Use of geiger counters and dosimeters

PLANETARY TILT, T.B. Holliday, Elmhurst College, Elmhurst, 60126.
A model to explain the occurrence and increase of planetary tilt is proposed. Tilt is the angle between the equatorial plane of the planet and the ecliptic plane of the solar system. The thermal history of the earth is correlated with the geologic history to show that glacial periods have occurred at periodic intervals at many points around the globe. Transfer of water from the equator to growing ice caps at the poles creates rotational instability that finally culminates in a movement of the crust to put the greater mass at the poles back on the equator. The moment of inertia of the shifting crust is about four percent of the mass underneath. Conservation of energy and angular momentum indicates that the movement of the crust through about 90 degrees has increased tilt by an average of about 2.5 degrees in each of about ten events. The model predicts that Venus has no tilt at present.

NORMAL MODES OF A COMPOUND STRING, Betty Windham, William Rainey Harper College, Palatine, 60067, Thomas D. Rossing, Northern Illinois University, DeKalb, 60115.

A partially unwrapped strong on a guitar provides a simple demonstration of overtones which are not harmonics of a fundamental. The modes of vibration can be predicted from solving the wave equation, but a simpler solution may be obtained by the application of transmission-line theory. The measured frequencies are found to agree closely with the predicted ones. This constitutes a novel and instructive experiment for an intermediate laboratory in acoustics.

SECOND-ORDER BEATS BETWEEN COMPLEX TONES., Kenneth Dols, Hampshire High School, Hampshire, IL 60140, Thomas D. Rossing, Northern Illinois University, DeKalb, IL 60115.

When two pure tones with frequencies f_2 and f_1, where $mf_2 = nf_1 + \varepsilon$, are sounded together, second-order beats can be heard when m and n are small integers. These are commonly called "beats of mistuned consonances", and are easily perceived in the case of the mistuned octave (n/m = 2), the fifth (n/m = 3/2), and the fourth (n/m = 4/3); for larger values of n and m, they become increasingly difficult to hear. In the case of pure tones, the periodic variations in intensity are less than 1 dB, and the ear detects pattern variations. If complex tones are employed, however, the effect changes. Complex tones with even-numbered harmonics introduce larger variations in intensity than tones with odd harmonics only. These beats, which can be explained by a simple model, could be of significance to the performing musician.

STILL ANOTHER PHYSICIST LOOKS AT BIOLOGY (With apologies to Max Delbruck), Richard S. Sakurai, Shimer College, Mt. Carroll, IL 61053.

Following Delbruck's two famous papers,[1] this paper describes how another physicist views theoretical biology. In a way similar to geometry, where there exist some so-called "Dual" theorems, it will be suggested that the Reductionist thesis of biology has a "dual". The implications of this will also be suggested.

[1]"A Physicist Looks at Biology," Trans. Conn. Acad. of Arts & Sciences, XXXVIII (1949); and "A Physicist's Renewed Look at Biology: Twenty Years Later," Science 168, 12 June 1970 (Nobel Lecture).

IMPULSES ON A FREE FALLING GYROSCOPE, John V. Werner, Bloomington High School, Bloomington, Illinois 61701.

One of the astronauts, using a straw, applied an impulse to a spinning gyroscope. The force was applied for a short time interval. This presentation is based upon an argument to convince the observer that the resulting motion is a translation through space in the direction of the applied force, with little apparent rotating motion in a direction perpendicular to the applied force.

Using Newton's Third Law, a discussion of an impulsive torque, conservation of energy and momentum, I reach a logical understanding of the observed motion. (Many physicists, while observing the film, were at first surprised at the resultant motion.)

SOUND PROPAGATION OUT OF AN OPEN PIT STRIP MINE, M. Nicholson and M. Hasan, Northern Illinois University, DeKalb, Illinois 60115.

Propagation of sound from a point source out of an open pit mine will be discussed along with the final solution of the wave equation, found by matrix manipulations on a programmable calculator. Applications to noise problems will also be discussed.

POST DEADLINE

NOVEL TREATMENT OF THE BOHR MODEL, Margaret S. Greenwood, DePaul University, Chicago, Illinois 60614.

A one-quarter course in modern physics for the liberal arts student will be described. Classical physics is discussed during the first four weeks and examples from modern physics are presented simultaneously. When presenting the Bohr model of the hydrogen atom, a relative set of units is used, where $e = 1$, $m_e = 1$, and $h/2\pi = 1$. When circular motion and Coulomb's law are introduced, the student sees that $F = ma$ becomes $v^2 = 1/r$. A table shows 11 values of r and v. When angular momentum is introduced, the student sees that angular momentum is an integer for only 4 entries corresponding to $n = 1,2,3,$ and 4. When conservation of energy is introduced, entries in the table are made for kinetic energy, potential energy, and energy E for the allowed orbits. The entries in the table show that $r = n^2$ and $E = -1/2n^2$. The advantage of this method is that no algebraic manipulation is involved and further, the quantization of angular momentum is readily seen.

FIRST QUARTERLY SYMPOSIUM OF GATEWAY CONSORTIUM FOR PHYSICS, David A. Cornell, Principia College, Elsah, Illinois 62028.

The newly formed cluster of institutions around Southern Illinois University has begun its program of activities. A prominent part of the program is the holding of quarterly symposia for the purpose of getting acquainted with the facilities of the various member organizations. The first such symposium was held February 20, 1976. This paper reviews that meeting for the Illinois Section. The presentation will feature the symposium program, slides of the various activities, and feedback from those in attendance.

THE NORMALIZATION OF THE COULOMB WAVE FUNCTION, Jose Maria Estrada and Ik-Ju Kang, Southern Illinois University, Edwardsville, Illinois 62026.

Analytical calculation of the normalization integral of the Coulomb wave function is carried out with the use of Cauchy's residue theorem on the contour integration of complex functions. The use is made of the usual convergence factor of $\exp(-\lambda r)$, where r is the distance between the source and the field points, λ is the parameter, which will approach zero in the limit. The result consists of the two terms; one the three dimensional Dirac delta function in the difference of the incoming and the outgoing momentum vectors, and the other which is proportional to the Kronecker's delta in the magnitude of the two momenta mentioned above. The second term is found to approach zero in the limit of the incoming momentum approaching infinity.

SCIENCE AND MATHEMATICS TEACHING
APPLIED SCIENCE AND TECHNOLOGY

SCIENCE AND ETHICS: AN INTER-DISCIPLINARY COURSE, Edwin J. Schillinger, De Paul University, Chicago, 60614. An Honors course, which can provide a model for a general education offering, will be described. It has been taught twice by faculty from Biology, Chemistry, Philosophy and Physics. Topics discussed include: the natures of science and ethics; the morality of science itself and the work of scientists; analysis of the impacts of selected technologies (such as warfare, reactors and genetic engineering); and the ways in which society can control science and its technologies. Among the reasons for the course's popularity are the facts that it shows a willingness of specialists to go beyond the confines of their disciplines, and it demonstrates the concern of science faculty for societal problems.

A study of the implementation phase of the Illinois Electricity -Electronics Curriculum Guide Project, Robert N. Woll, Northern Illinois University, DeKalb, IL 60115. This report will describe the second phase of a project reported on at the Academy last year by the author. The origination and development was described at that time. The project is now being implemented and will be reported on. This curriculum project involves direct industry based input in the preparation of a guide to be used by the secondary teacher of electronics. The implementation phase involves the presentation of workshops which will be described.

USING COMPUTER AIDED CIRCUIT ANALYSIS IN THE CLASSROOM
Lester Knapp, Northern Illinois University, DeKalb, IL 60115

Using a computer as a tool to demonstrate electronic circuit actions, students are able to observe circuit responses with changing parameters, without the danger of burning up parts and destroying meters. This concept is built around a Circuit Analysis program generated by the NIU Electrical Engineering Technology students. As computer core requirements are small and programming data simple, students at high school levels of physics and electronics can learn it quite readily, opening up a new opportunity for studying electronic circuits.

RELATIONSHIP BETWEEN INFORMATION STORAGE AND ITS PROCESSING IN INTELLIGENCE AND CONSCIENCE BUILDING UP.
Vlamidir Iuliu GUSIC, Alexandru IONESCU, Mircea DUMITRU
National Institute of Gerontology, Academy of Agric. Sciences - Bucharest - Romania.

Evalution of intelligence and creative intellectual capacity in relationship with information storage and processing as well as the caracteristics of both pathways of information, ciroulation (rational and affective), the control of primary personality by the superego level, by a feed-back of information about self personality and behaviour are the topics of this paper.
In this article the involvement in teaching systems and psychopathology of normal and pathological information, circulation and processing is considered too.

A HIGH-POWER LOW-NOISE AMPLIFIER FOR MICROWAVE AND MILLIMETER WAVE SIGNALS, Chang E. Kang and B. Ho*, Northern Ill. Univ., DeKalb, 60115.
A new mode of transverse beam wave interaction is described. Both the coupled-mode method and electron dynamic approach are used to analyze the interaction. Conditions required for the existence of the interaction as well as the gain expression are obtained. Extremely low noise and wide band characteristics are anticipated from this interaction mechanism for frequencies well into the millimeter wave region. Results of the experimental tubes are presented.

* B. Ho is an associate professor of Michigan State University

WHY CAN'T JOHNNY MEASURE? Thomas D. Rossing, Northern Illinois University, DeKalb, 60115.

Science and technology have always made stringent demands on the ability of their practitioners to make reliable measurements and to analyze the data gathered from these measurements with minimum error. However, there are many other facets of society where these skills are vitally important, also. This paper contends that measurement and data handling are frequently not given enough stress in our laboratory courses and suggests ways in which this situation might be improved.

TOOLS TO DISCUSS THE ENERGY CRISIS, Octave J. Du Temple, American Nuclear Society, Hinsdale, 60521. Many pamphlets, books, reports, slides and movies have been prepared to explain the energy requirements of the USA and possible means of supplying adequate energy for the next 25 years. Information from the Energy Research and Development Administration, the Federal Energy Agency, some energy companies and various scientific and engineering societies will be discussed as possible classroom aids. The relative importance of energy from coal, nuclear, fusion, solar, geothermal and wind based on anticipated technology developments in the next 25 years will be shown. A bibliography will be given to attendees at the session.

ZOOLOGY

A SURVEY OF THE HERPETOFAUNA ALONG THE UPPER DES PLAINES RIVER VALLEY, LAKE COUNTY, Illinois, Charles L. Bushey, Lake County Forest Preserve District, Libertyville, 60048. A survey of the herpetofauna population of the Des Plaines River Valley in Lake County, Illinois was conducted on District owned and proposed lands from April 2, 1975 to October 15, 1975. Specimens were collected by live trapping, hand capture and seining. Identification was also made by field observation of specimens and recognition of breeding calls. A list of species expected to be found in the study area was compiled and is presented with a list of species found. Twenty-five species were determined to actually inhabit the river valley, one species was found that was not expected and was probably a "pet release." One intergrade between two sub-species was also determined.

FALL BREEDING OF TWO SPECIES OF LEOPARD FROGS, Carol B. Axtell, Lewis and Clark Community College, Godfrey, Illinois, 62035. Field studies were made in 1972 and 1973 to determine if Illinois and Missouri populations of R. blairi and R. utricularia were breeding in the fall. Auditory observations and tape recordings demonstrated that both R. blairi and R. utricularia congregate in breeding choruses in the fall. Electrophoretic analysis for the enzyme lactate dehydrogenase showed that egg clutches of R. utricularia were laid and that tadpoles successfully overwintered. No eggs or overwintering tadpoles of R. blairi have been found yet.

THE CHROMOSOMES OF TWO KARYOTYPICALLY DISTINCT FRESHWATER FISH AND THEIR FERTILE HYBRIDS, Gregory C. Cuca, Southern Illinois University at Edwardsville, 62025. The sibling species Fundulus notatus and Fundulus olivaceus have different diploid chromosome numbers and readily interbreed in the laboratory producing fertile hybrids. Karyotypes were analyzed from gill epithelial cells of colchicine treated progeny resulting from homospecific and heterospecific matings. The results indicate a high degree of homology in the chromosomal arms of the two species and compare with the published data on rare natural hybrids. A possible mechanism explaining the F_1 fertility will be discussed.

CONVERGENT EVOLUTION IN THE HYLID FROG ANOTHECA, Linda Maxson, University of Illinois, Urbana, 61801. It has been unclear whether the monotypic genus Anotheca is phyletically within the subfamily Hylinae or Amphignathodontinae. Based on considerations of external morphology it is in the Amphignathodontinae. Comparisons of serum albumins of 19 hyline and 7 non-hyline species were performed by a quantitative immunological approach. The results showed Anotheca to be a hyline frog. The large distance found between Anotheca and Gastrotheca (Amphignathodontinae), along with our albumin phylogeny for the Hylidae, show these genera are only remotely related and suggest the morphological similarities between them arose by convergent evolution.

ENZYMATIC CHANGES IN REGENERATING AMPHIBIAN LIMBS FOLLOWING DENERVATION. Frank Morzlock, Claire Zacharias and Christine Winn. Chicago State University, Chicago, Ill. 60628. The effect of denervation on activities of lactic acid dehydrogenase, malic acid dehydrogenase, glucose-6-P dehydrogenase, acid phosphatase and β-glucuronidase in regenerating limbs of the adult newt, Triturus viridescens, were determined using conventional, in vitro, techniques. Dehydrgenases showed no change in their activities following denervation, whereas activities of β-glucuronidase and acid phosphatase increased by 60-70%. These results indicate that atrophy and resorption of denervated regenerating tissue may be primarily due to an increased activity of hydrolytic enzymes.

DIRECT CALORIMETRY OF EASTERN BOX TURTLES (TERRAPENE CAROLINA), Richard W. Elghammer and Robert E. Johnson, Knox College, Galesburg, Illinois, 61401. Heat production by eastern box turtles (Terrapene carolina) was measured directly. Animals were kept at 27°C by day and 22°C by night. Their diet was a mixture of animal and plant foods supplemented with vitamins and bone meal. The light cycle was 12 h. daylight and 12 h. darkness. The calorimeter was a 4 l Dewar flask kept in an insulated box at 24±1°C. Animals were studied singly for 12 h. without food or water. The system was calibrated with water. The mean heat production was a steady 0.12 cal $h^{-1}g^{-1}$ (0.50 J $h^{-1}g^{-1}$) by fasting animals resting in the dark at 24°C. The box turtle may be considered a heterotherm not a poikilotherm.

BLOOD CHEMISTRY IN COMMON ECTOTHERMS, Harold M. Kaplan, Samuel Smith and John Shepard, Southern Illinois University, Carbondale, 62901. Blood enzyme and other chemical values known to be of clinical importance in man were determined in frogs and turtles, by instrumentation employing only micro quantities but allowing differentiation between the normal and abnormal. Some of these chemicals exist in quantities the same as or even higher than in mammals including man. Some of the chemicals differ significantly between frogs and turtles. They show no sex differences within a single species. The data have an importance in evolutionary consideration as well as in laboratory animal science.

A COMPARISON OF BREEDING-BIRD POPULATIONS OF FOUR HABITATS IN WESTERN ILLINOIS, Linda M. Hall and Edwin C. Franks, Western Ill. Univ., Macomb, 61455. Plot censuses employing the "mapping method" were conducted in a cultivated field, pasture, pine forest, and deciduous forest in Warren and Henderson counties. Census results were used to estimate the breeding territories present on each plot. Comparisons have shown that the deciduous forest had the greatest breeding-bird density, number of species, and index of species diversity. The pine forest ranked second in all these respects; the pasture, third; and the cultivated field, last. Lower bird density and diversity seemed to be associated with uniformity in types of vegetation present and lack of variety in foliage heights.

COMPARATIVE MORPHOLOGY OF SPERMATOZOA FROM BATS OF THE FAMILY PHYLLOSTOMATIDAE: TAXONOMIC IMPLICATIONS, G. Lawrence Forman, Rockford College, Rockford, Illinois 61101. Spermatozoa from 35 species of leaf-nosed bats were measured and described with respect to characteristics of the nucleus, head cap, and midpiece. Head caps of bat spermatozoa were described for the first time. They were more variable in form than the nuclei. Spermatozoa of phyllonycterines had particularly well developed, notably asymmetrical head caps. Spermatozoa of stenodermines and sturnirines were extremely similar supporting the proposed close taxonomic affiliation of these groups. Those of Macrotus, Centurio, Chiroderma, and Diphylla were most unusual and revealed the development of structural uniqueness in spermatozoa within several highly divergent subfamilies. Those of the three vampires differed from other phyllostomatids in certain features but they are similar to them in general characteristics.

EFFECTS OF SIMULATED HIGH ALTITUDE (22,000 FT.) ON THE RAT AND THE THIRTEEN-LINED GROUND SQUIRREL (SPERMOPHILUS TRIDECEMLINEATUS), John M. Connors, Loren G. Martin and David L. Cooper, Dept. of Physiology, University of Illinois at the Medical Center, Chicago, 60612; and Dept. of Basic Science, Peoria School of Medicine, Peoria, 61606. A comparison was made of the acclimation of the thirteen-lined ground squirrel and the rat to simulated altitude. Parameters selected for observation included the following: hematocrit ratio, hemoglobin concentration, right ventricular hypertrophy, myocardial anoxic resistance, and thyroid function. Both species exhibited an increase in Hct. and [Hb] upon altitude exposure. Myocardial anoxic resistance was found to be greater in the sea-level ground squirrel than in the sea-level rat. This parameter increased significantly in altitude animals of both species. A relative thyroid hypofunction was found in high altitude animals of both species. (Supported by P.H.S. Gen. Res. Support Grant #5S01RR05369-12)

INTERRELATIONSHIP BETWEEN THYROIDAL FUNCTION AND CHRONIC HYPOXIA IN THE JAPANESE QUAIL, Loren G. Martin, James J. McGrath, John M. Connors, David L. Cooper and Sharon S. Murnane, Department of Basic Science, Peoria School of Medicine, Peoria, 61606; and Department of Physiology, University of Illinois at the Medical Center, Chicago, 60612. Japanese quail were exposed to a simulated high altitude of 6,100 m above sea level for 4 weeks. Control animals were maintained in an identical chamber under sea level conditions. Hemoglobin and hematocrit values were significantly elevated at the end of the exposure period. T_4-CPB methodology demonstrated a significant reduction in total circulating thyroxine as a result of chronic exposure to simulated high altitude. (Supported by PHS GRSG 5S01RR05369-12, awarded to the University of Illinois College of Medicine and Illinois Heart Grant-in-aid #74-3).

COMPARISON OF T_4-CPB AND RT_3U TESTS IN ANALYZING THYROIDAL FUNCTION IN THE RAT AND IN THE JAPANESE QUAIL, Loren G. Martin, James J. McGrath, John M. Connors, David L. Cooper and Sharon S. Murnane, Department of Basic Science, Peoria School of Medicine, Peoria, 61606; and Department of Physiology, University of Illinois at the Medical Center, Chicago, 60612. Competitive protein binding analyses (T_4-CPB) and radioactive triiodothyronine uptake tests (RT_3U) were conducted on sera obtained from normal control rats and quail and from hypothyroid (6-propyl-2-thiouracil blocked) rats and quail to determine the efficacy of utilizing these common thyroid tests in both animals. It was demonstrated that both increases and decreases in thyroid function are reliably measured by the T_4-CPB test in rat and in quail sera, while the RT_3U test is useful only in measuring decreased thyroxine in rat sera. (Supported by PHS GRSG 5S01RR05369-12, awarded to the University of Illinois College of Medicine and Illinois Heart Grant-in-aid #74-3).

FEEDING ACTIVITY RHYTHMS IN FEMALE GUINEA PIGS, Mary Hess and E. P. Wallen, University of Wisconsin-Parkside, Kenosha, 53140. Early work by Dempsey et. al., J. Physiol., 1934 demonstrated that estrous behavior in guinea pigs occurs primarily during the dark portion of the light:dark cycle. The following experiments were designed to test whether another behavior, feeding activity (FA), is also influenced by the photoperiod. FA was monitored continuously by means of a sensitive micro switch mounted on the feeder and connected to Esterline Angus analog recorders. Appetitive behavior was transduced into deflections on a slowly moving chart. In animals maintained under 14 light:10 dark conditions, 33.7% of the FA was confined to the dark, 8% less than would be expected from regular feeding intervals during a 24 hr. period. FA was unrelated to the lights "on" or "off" signals. These data demonstrate that photoperiod is a weak Zeitgeber for FA in female guinea pigs.

TIME-DEPENDENT EFFECT OF PINEAL GLAND REMOVAL ON SECONDARY SEX GLANDS IN THE MALE RAT, John Georgeson and E. P. Wallen, University of Wisconsin-Parkside, Kenosha, 53140. Experiments were performed to determine if removal of the pineal gland (pinx) alters the growth of androgen-dependent sex glands in male rats. Mature male Sprague Dawley rats maintained under a control photoperiod of 14 hrs. light: 10 hrs. dark were pinx or sham pinx on day 0 and autopsied either 6, 12, or 30 days later. Accessory gland weights in rats pinx for 30 days were elevated significantly ($p < .001$) when compared to 30 day shams or to the 6 and 12 day groups. These data confirm the antigonadal potential of the pineal gland in male rats and extend these findings to indicate that the response of accessory glands to pinx is time-dependent.

PINEAL HYDROXYINDOLE-O-METHYLTRANSFERASE IN THE FEMALE HAMSTER DURING THE ESTROUS CYCLE AND SHORT DAYS, Susan Losee and E. P. Wallen, University of Wisconsin-Parkside, Kenosha, 53140. Studies were undertaken to determine the pattern of hydroxyindole-O-methyltransferase (HIOMT),in the hamster during the reproductive cycle and during artificial short days (6L:18D). HIOMT synthesizes a putative pineal hormone, melatonin, which possesses antigonadal effects. Enzyme assays were performed on individual pineal glands three times daily (0900, 1700 and 2300 hrs., 6 hamsters/point). During the estrous cycle enzyme activity varied between 30-46 p moles/gland/hr, but a significant diurnal rhythm was not present. The short day photoperiod caused hamsters to become acyclic and significantly suppressed HIOMT activity when compared to cycling hamsters. These data demonstrate a correlation between pineal metabolism and alteration in the reproductive competence of female hamsters.

THE PREPUTIAL GLAND AS THE SOURCE OF THE ESTRUS-INDUCING PHEROMONE IN MICROTUS OCHROGASTER, Glenn Netto and Vernon Pederson, Western Il. University, Macomb,61455. A study was done to prove that the preputial gland of the male prairie vole, Microtus ochrogaster was the source of an estrus-inducing pheromone. Females were subjected to 3 bioassays: control treatment; odor treatment from preputialectomized males; and odor treatment from males with intact preputial glands. Vaginal smears were taken daily on perforate females, female reproductive tracts were removed, fixed and weighed and histological studies of ovaries and uteri were examined. Results indicate that females exposed to male preputial gland odor show a distinct rise in vaginal, ovarian and uterine activity. Thus, the male preputial gland is the source of an estrus-inducing pheromone.

A REEVALUATION OF REPRODUCTIVE PERFORMANCE IN MICROPTHALMIC RATS, D. Reed Jensen and Jim N. Tone, Illinois State University, Normal, 61761. The reproductive performance of micropthalmic rats, Browman strain, was studied. The usual 70% litter mortality of this strain was attributed to lactational failure by the parturient female and starvation of the young. A deficiency in pituitary prolactin secretion was suggested. Breeder rats were obtained from the Browman colony. Females were bred and allowed to litter and nurse in wire-bottom, stainless steel cages. Litter survival for 3 successive deliveries by each of 3 females was 0%. A plastic cage was adopted for pregnant females which provided freedom of movement and nesting opportunity. Twenty females allowed access to the "nursery cage" for 3 successive deliveries had a 90-95% litter survival. It is indicated that adequate prolactin secretion does occur and maintains the lactational response--providing that optimal delivery and nursing conditions are provided the pregnant females.

THE ACCUMULATION PATTERN OF INGESTED GOSSYPOL IN SELECTED ORGANS OF THE RAT, Jim N. Tone and D. Reed Jensen, Illinois State University, Normal, 61761. A study was conducted using rats to determine the effect of the length of the feeding period on the accumulation of gossypol in the liver, lungs, kidneys and spleen. The dietary level of free gossypol was 0.98% and the periods of feeding were 6, 14, 28 and 35 days. The bound gossypol level in the spleen and liver was directly related to the length of time the diets were fed. Free gossypol level in the kidneys, spleen and lungs increased for 14 days and then tended to decrease as the feeding period was extended.

SOME FACTORS AFFECTING DIVING REFLEX IN MAN, Dexter F. Speck and David S. Bruce, Wheaton College, Wheaton, 60187. The roles of water, temperature, and apnea in the development of the diving reflex were examined in 33 untrained human subjects. Heart rate and brachial blood pressure were measured in nine phases of experimentation. Blood pressure and heart rate were observed to be inversely related. Nonapneic face immersion produced a significant bradycardia ($p < .001$), although it was less pronounced than that of either apneic immersion or apnea with facial cooling. Results indicate that both apnea and the cooling of the nasal region are important to the establishment of the diving reflex.

Prevalence, life cycle and pathogenesis of Diplostomulum sp. from the retina of the yellow perch (Perca flavescens). Huizinga, H.W., Dept. of Biological Sciences, Illinois State University, Normal 61761 and Lester, R. J. G., Dept. of Parasitology, Univ. of Toronto, Canada, Metacercariae of Diplostomum sp. were recovered from the retina of 99 of 115 (85%) yellow perch. Right and left eyes were uniformly infected with a mean of 23 metacercariae per eye. The larvae were clustered in a space between the epithelial pigment and photoreceptor cell layers of the retina. The larvae caused severe local disruption and compression of the retina, but there was no inflammation. The life cycle was experimentally shown to include a lymnaeid snail (intermediate host) and herring gull (definitive host). In experimental infections, the larvae showed a specificity for the retina of the perch, but did not develop in the retina of goldfish, lake trout or sucker. A related species, D. spathacaem, developed in the lens, but not in the retina of perch. Survey, life cycle, and histopathology are described.

NEMATODE AGE AND TRAP FORMATION IN ARTHROBOTRYS CONOIDES, Benedict J. Jaskoski and Mary Lou Tortorello, Loyola University, Chicago, 60626. Objectives of the investigation were analyses of the possible influence on the mean number of traps formed by Arthrobotrys conoides by the nematode Panagrellus silusiae. L_2 stages of the nematode were separated in columns of glass microbeads. Stages L_3, L_4, and L_5 were separated by synchronous melting of L_2. Fungus was maintained on corn meal agar in Petri plates. Total protein for each aliquot of nematodes was determined using the Lowry method. The mean number of traps formed per mg of protein for each larval stage was: L_2-18.3; L_3-321.1; L_4-505.1; L_5-334.1. No traps formed on controls. Significant increase in trap formation took place between L_2 and L_3 stages.

STUDIES OF AGING PATTERNS AND PHOSPHATASE ISOZYMES IN THE LIFE CYCLE OF THE NEMATODE PANAGRELLUS SILUSIAE, E. E. Palincsar and Glenn N. Doering, Department of Biology, Loyola University of Chicago, Chicago, Illinois 60626. Utilizing the techniques of disc electrophoresis the isozyme patterns of acid phosphatase were determined over the life cycle of the nematode. Acid phosphatase was used as an index of lysosome or lytic enzyme activity. Electrophoretic mobility (Ef) values were used to identify enzyme bands and the bands were coorelated with the age of the nematode. The patterns fluctuated according to the age of the nematodes and a unique species of enzyme was identified as being dramatically different from related isozymes. Lysosome activity increased with senescence as indicated by our data.

Na^+-DEPENDENT TRANSPORT OF ALANINE ACROSS THE BODY WALL EPITHELIUM OF GLYCERA DIBRANCHIATA, Bruce R. Stevens and Robert L. Preston, Illinois State University, Normal, 61761. Body wall segments of the marine worm, Glycera were mounted in a modified Ussing chamber, and the external surface exposed to L-(U-^{14}C) alanine and ^3H-inulin (for extracellular space determination) in aerated sea water at pH=7.8, 12.5° C. Subsequent influx was measured by liquid scintillation counting. In 440 mEq/l Na^+ sea water alanine influx across the body wall epithelial membrane is stimulated 15-fold over choline substituted sea water. The apparent K_t for alanine in the presence of Na^+ is $8.6 \pm 0.2 \times 10^{-5}$ M, while the J_{max} is $1.38 \pm 0.02 \times 10^{-7}$ mole/hr/cm^2. Fractionation of the tissue after 100 minutes of incubation indicates that over 90% of the transported alanine is not metabolized. The Na^+ gradient determined by flame photometry is 11:1 (sea water:tissue). The presence of this large Na^+ gradient, and the Na^+ stimulation of alanine influx suggests a Na^+ coupled transport mechanism for alanine.

MODULATION OF THE TISSUE LEVELS OF THE OXIDATIVE NADP-ENZYMES BY DIETARY CARBOHYDRATE IN DROSOPHILA MELANOGASTER, C. G. Woodward, C. J. Czuprynski, J. V. Swearingen and B. W. Geer, Knox College, Galesburg, 61401. Tissue levels of glucose-6-phosphate dehydrogenase and 6-phosphogluconate dehydrogenase increase in response to dietary sucrose in larvae. By feeding compounds convertible to glycolytic intermediates, it was found that a derivative of glyceric acid may be the inducer of the pentose shunt enzymes in Drosophila. Metabolite and cofactor concentrations in the larvae indicate that glyceric acid and sucrose exert similar effects. The tissue levels of other enzymes involved in lipid and carbohydrate biosyntheses are also influenced by dietary sucrose.

A DIETARY DEFICIENCY THAT ALTERS MUTAGEN SENSITIVITY IN DROSOPHILA MELANOGASTER, D. L. Reno and B. W. Geer, Knox College, Galesburg, 61401. Two day adult males raised on an optimal diet or a diet deficient for choline were fed a 5% aqueous sucrose solution containing 10^{-5} M Trenimon for 17 hours. The treated males were mated to successive groups of 4-day old Basc females to yield three 4-day broods. Although there was no brood 1 difference, the X-chromosome recessive lethal mutation frequencies for brood 2, derived from treated early stage spermatids and spermatocytes, and brood 3, representing treated spermatogonia, were significantly higher for choline-deficient test males than males fed an optimal diet. The spontaneous mutation rate was not altered by the dietary deficiency.

GENETIC BASIS OF LONGEVITY IN DROSOPHILA MELANOGASTER, Betty Rossbach and Kandy Baumgardner, Eastern Illinois University, Charleston, 61920. Survivorship curves for four strains of D. melanogaster were determined under identical environmental conditions. Consistent differences in longevity were observed among the four strains, indicating strong genetic influence on survivorship. Interstrain reciprocal crosses and F_1 x F_1 crosses were made to determine the extent of genetic influence on longevity. Hybrid vigor was observed in all interstrain crosses. Based on a polygene model, F_1 and F_2 survivorship curves are currently being analyzed to determine the number of genes controlling survivorship in this species.

A DESCRIPTION OF DESERT DROSOPHILA DEMES, Stephen H Bryant, Western Ill. University, Macomb, Ill. 61455 Second chromosome lethals were extracted from four populations of D. pseudoobscura in Southern California. Allelism tests were done on the lethals within and between all locations. Intrapopulational allelism rates were, with one exception, the same as the interpopulation rates (0.005). The interpopulation rates are significantly lower than Dobzhansky's results for the third chromosome. This may be due to lethals being linked to heterotic third chromosome inversions in Dobzhansky's work. The allelism rate of the exceptional population (0.01) is probably due to heterotic lethals in that population. Ecclogical work is also reported that shows D. pseudoobscura can move at least 8 km in 24 hours, and actually breed in small desert oases.

EFFECTS OF TEMPERATURE AND THERMAL ACCLIMATION ON THE BIOLOGY OF TENEBRIO MOLITOR, Fred Punzo, Blackburn College, Carlinville, 62626. Studies were conducted to ascertain the effects of temperature on the survival capacity, larval thermal tolerance, adult longevity and oviposition rate of this tenebrionid beetle. Embryological development was successful at moderate temperatures but not under arid conditions. The pupal stage is the most resistant to temperature and moisture extremes. At all non-lethal temperatures, females exhibit longer life spans than the males regardless of humidity. Arid conditions (12% rh) drastically reduce oviposition rates.

THE EFFECTS OF ACCLIMATION ON THE UPPER LETHAL TEMPERATURE OF THE DRAGONFLY NAIAD, PLATHEMIS LYDIA, David Fritz and Fred Punzo, Blackburn College, Carlinville, 62626. Naiads exposed to high water temperatures for 60 minutes were observed for recovery during a 48 hour period. Under normal rearing conditions of 20°C, the upper lethal temperature was found to be 43°C. Acclimation at 5°C for 9 days lowered the lethal threshold to 42°C. Insects acclimated at 36°C for 4 days exhibited an upper lethal temperature of 43.5°C. Mortality differences at 42° and 43°C among acclimated groups were significant ($p<.01$). This study represents the first available data concerning thermal acclimation for this species.

THE DEFENSIVE STRATEGIES OF SCEPSIS FULVICOLLIS HÜBN. (LEPIDOPTERA: CTENUCHIDAE). David Evans, University of Illinois, Urbana, 61801. The behavior of S. fulvicollis and its relative palatability to birds were examined. Under controlled conditions captive birds rejected fresh frozen specimens; like other aposematic and distasteful moths, such as Diacrisia virginica Fab., it does not take flight when disturbed. The cryptic and palatable Heliothus zea (Boddie) and Drasteria crassiuscula Haworth usually take flight readily if disturbed. Male S. fulvicollis have a pair of long eversible tubes on the abdomen, but whether or not they function in defense is not known.

TRENDS IN AUTUMN HAWK MIGRATIONS, Kopeny, Mark and Holdaway, Paul, Harper Community College, Palatine 60067. This report was to discern the main factors which prompt certain raptors to migrate south. This study occurred in a bird banding station about one-half mile from the western shore of Lake Michigan in Lake County, Illinois, during the fall migration of 1973-75. This area is well known as a flyway. Nine species of birds were studied of the genera: Falco, Buteo, Accipiter, Pandion, and Circus. Various weather conditions were recorded, such as time of day, temperature, wind velocity and species type. Instinct seems to be the overall ruling force within all species, especially Falco. Harsh weather effects the smaller, more fragile hawks, like Sharpshins. Food shortage does not seem to effect most species, except in extremely northern areas where snow fall occurs early.

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BEHAVIORAL ITEM REDUCTION PROGRAM FOR PRECEDES/FOLLOWS CONTINGENCY TABLE FORMAT FOR DATAMYTE RECORDED BEHAVIORAL EVENTS

Jack A. Ward, Biological Sciences; Richard H. Miller[1)], Psychology, Ramesh Chaudhari and Steve Skinner, Computer Services; Illinois State University, Normal 61761

ABSTRACT

A unique program for computer reduction of behavioral data is described. The recording system is commercially available, inexpensive, portable, and requires no previous knowledge of electronics and engineering as previous data retrieval systems have required. The recorded behavioral data is simply interfaced with the computer and the program to be described reduces the data onto three N x N contingency tables which allows rapid interpretation of events recorded. The amount of information produced is greater than any other method currently available to ethologists and other behavioral scientists.

INTRODUCTION

Observers of animal behavior are often limited by their inability to record several kinds of data simultaneously, e.g. frequency and duration. When this is possible the extraction of the information from charts or magnetic tape is a cumbersome and time consuming job. White (1971) made the initial break through in recording behavioral events on magnetic tape and subsequent interfacing to a computer. Dawkins (1971) gave instructions for a more portable system that also recorded behavioral events on magnetic tape and which was later played through a simpler interface to the computer. Both systems simultaneously recorded the time of behavioral events. Dawkins (1971) noted that his system could not record duration of behavioral events. Fernald and Heinecke (1974) described yet another system whereby the observer punched a key on an event recorder which was then directly punched on paper tape thereby eliminating the intervening step of recording first on magnetic tape. All of these earlier prototypes required considerable knowledge of engineering and electronics and the observer had to construct part of the hardware himself. These earlier systems did reduce the amount of time employed in collecting and tallying behavioral events, however, the computer printouts simply listed the sequence of behavior as it occurred when recorded. None of these systems actually reduced data into a form that allowed immediate interpretation of behavioral events.

---

1) Current address: Department of Psychology, Washington University, St. Louis, Mo.

The system we describe is commercially available[2], inexpensive, portable, and requires no previous knowledge of electronics or enginnering to operate it. A new recording device[2] resembling a 10-key calculator permits accurate, simultaneous recording; depression of keys not only records digital information on magnetic tape, but simultaneously records the time of the event in relation to events that preceded or those to follow. Furthermore, we have designed a program that reduces the behavioral information recorded into a format that allows immediate interpretation of observations. The program first corrects data for internal and observer-generated errors and then reduces data on three N x N contingency tables. The first table is a precedes/follows frequency matrix that lends itself quickly to many methods of sequence analyses (Slater, 1973). The second contingency table scores time elapsed between all precedes/follows couplets and the third table is a time delayed matrix accumulating time between all possible couplets regardless of their precedes/follows relationship. The amount of information generated is greater than any other method currently available to ethologists and other behavioral scientists. Ward developed the concept of the program and its need in behavioral research; Miller (1975) developed the prototype for the correction portion of the program; while Ramesh Chaudhari and Steve Skinner designed and wrote the program.

PROCEDURES

The program described below was constructed for use with the DataMyte DAK-8 portable data collector that interfaces the computer by the retrieval of magnetic tape recorded data via a coupler[2] onto paper punch tape. The reduction program is also suitable for use with the new DataMyte 9001 (solid-state) portable data collector that interfaces directly with the computer. The details given below for recording are necessary for smooth and uninterrupted operation of the reduction program and are tailored for the DataMyte DAK-8.

DATA COLLECTION (use of hardware):

IMPORTANT: Follow all directions.

A. DISENGAGE RECORDER FROM CHARGER ATTACHMENT -- Place a cassette tape into the recorder (tapes should always be bulk erased before use) -- set recorded in "PLAY" position for a few seconds until tape has tightened -- make sure, if the cassette is being used from the beginning that the tape

---

2) Manufactured by Electro/General Corporation, 14960 Minnetonka Industrial Road, Minnetonka, Minn. 55343

progresses beyond the clear leader to the dark recording surface. (Note: When using a cassette, whether at the beginning or at any point in its length, position the recorder in play position for a few seconds to tighten the tape.)

B. CONNECT KEYBOARD TO RECORDER -- When the recorder is connected to the keyboard it will not operate in "fast forward", "rewind", or "play" modes; to do so it must be disconnected from the keyboard.

C. CHECK TO SEE THAT CLOCK IS IN "ON" POSITION -- Turn keyboard over - lever should be in the direction of the arrow for the "on" position.

D. PUT RECORDER IN "RECORD" MODE

E. TURN POWER SWITCH ON KEYBOARD TO "ON" POSITION - WHEN "ON" RED LIGHTS WILL APPEAR IN DISPLAY WINDOW -- If red lights flash this indicates low voltage and any data recorded will be lost; recharge recorder a minimum of two hours or obtain a freshly charged battery pack.

F. INTRODUCTORY INFORMATION -- The program prior to data entry reads for introductory information fields with a maximum of 10 digits per field; you must enter information into all fields specified to initiate data acquisition. Any information may be entered into the nine fields that the observer wishes, however, the program PRINTS the following when the data are actually reduced:

Experimenter's # :

Description:

# of Variables:

# of Subjects:

Date and Time:

Machine Ser # :

Total Exp Time:

FIELD #

1 enter NUMBER OF VARIABLES - followed by ENTER (number of variables limited to 25!)

2 NUMBER OF SUBJECTS - ENTER

3* MONTH - ENTER e.g. 7

4* DAY OF MONTH - ENTER e.g. 4

5* YEAR - ENTER e.g. 1776

6* TIME OF DAY (hour, minute) - ENTER e.g. 1750 = 5:50 p.m.

7 SERIAL NUMBER - enter serial number found on back of keyboard - - ENTER

8 EXPERIMENTER NUMBER- ENTER

9 ANY OTHER DESCRIPTIVE DATA YOU WISH: not to exceed 6 digits---ENTER

* = fields 3 to 6 printed as one line "Date and Time"

FIELD #10 will be read as the first data entry. BUT FIRST --- TURN KEYBOARD POWER SWITCH "OFF"! When it is turned back on, either 2 seconds or 2 hours later, it will reset the clock to zero and is a crucial step. If the observer forgets this step the correction portion of the program will correct the time of the 10th field as 0000, and you will be warned of this error. Elapsed time during the observation will be accumulated by the recorder. If time duration is crucial the observer must use an external timer.

WHEN YOU ARE READY TO BEGIN YOUR EXPERIMENT - TURN POWER SWITCH TO "ON". Enter your first event. This entry will establish ZERO TIME (0000).

DATUM #

1 45 (do not exceed 10-digit codes; maximum number of data points per observation period = 500) - ENTER

2 12 - ENTER

500 Etc.- ENTER

When the LAST datum is entered, or experiment ends, the observer must signal "the end" of data by - - - - - - -

9999 - ENTER

TURN POWER "OFF" - This resets the clock and the observer can repeat all steps for a second observation period. The recorder only functions when actual data is entered. A 20-minute observation period may be represented by only 2 minutes of tape. Remove cassette without rewinding - if used again it will be at a point ready for continued recording. The tape can be rewound, but if it is to be used again without first being bulk erased, the exact location where data entry concluded before must be located. Play the tape and adjust the volume on the recorder so the

digital tones can be heard of your previous recording. A silence of tones will be unused tape.

ERROR MESSAGE - You can correct information entered wrong. For example, suppose a 44 - ENTER, should have been a 4 - ENTER. It could be corrected in the following manner - - - - - - -

44 - ENTER, 0 - ENTER, 4 - ENTER

Thus, the 0 - ENTER following a datum removes that datum and it will be replaced by the correction given after 0 - ENTER. The corrected datum will be designated as occurring at the same time at which the erroneous datum was entered.

The number of corrections that can be made is infinite as long as two error signals do not follow one another, for example, 0 - ENTER; 0 - ENTER.

(The correction of Introductory Information can be made in the same way. Again, the number of corrections possible is infinite.)

RECORD-PLAY BACK COMPATIBILITY - If the original DataMyte recording equipment is used it is recommended that the recorder used to record data is the same recorder used to interface the coupler. Alignment varies from one recorder to another and using a different recorder to interface the coupler may result in erroneous "nonsense" data. It is impossible to keep recorders perfectly aligned at all times. Alignment can also be a problem even when using the same recorder if the experimenter allows a considerable time lapse between data recording and transcription. Therefore, it is also recommended that data on cassette tapes be transcribed and committed to a more permanent file form (e.g. paper punch tape) as soon after recording data as possible.

REDUCTION OF DATA (use of software):

In most instances the data contained on the magnetic tape for each observation period will be transferred to punch paper tape. Whatever method is chosen to interface the computer it is recommended that temporary or permanent data files be created for each observation period. It is further assumed in what follows that data manipulation, reduction, and summation will be done at a remote terminal.

The reduction program constructs precedes/follows contingency tables and has two parts -- first the data file is corrected and then secondly the data is reduced and displayed on N x N contingency tables, the process is continuous, however.

When the program is called up at a remote terminal it addresses the operator with a number of possible options which are:

HOW MANY FILES DO YOU WANT TO ACCUMULATE?

WHAT IS THE MAXIMUM CODE? (Select a realistic maximum that is in agreement with your code system - if the codes were 1 through 25, for example, the maximum should be selected as 25. Erroneous code words will be counted as variables and added to the final matrices. Only 25 variables are allowable and real code words plus erroneous codes may exceed this maximum.)

WHAT IS THE MAXIMUM TIME? (Choose a realistic time maximum, one that corresponds to the real time limit of the observation periods.)

DO YOU WANT A DATA LIST?

WHAT IS THE NAME OF THE NEXT FILE? (This statement will be repeated an equal number of times to the number of data files you are accumulating.)

I. CORRECTION OF DATA

A number of errors can occur either by entry of erroneous data by the observer or in many cases "nonsense" data entry occurs as an idiosyncrasy of the recorder and recording system. The program corrects for nine sources of potential error. Most corrections are not corrections per se - the program simply eliminates the entire entry that has certain specified illegal parameters. If paper punch tape is used the observer has the option of making manual corrections in which case the erroneous entries can be transformed into legitimate entries, particularly if the observer can recall the missing datum and its inclusion is desirable. In our experience the amount of errors generated is most often less than .01 of the total amount of data entered. Whether the observer chooses to ask for a data list or not the following corrections will be made on the data file(s) called up. If a data list is asked for the location of the error and its kind is noted.

1. ILLEGAL CHARACTER OR BLANK OCCURRED: For example the skip key on the DataMyte recorder produces an "*" -- an illegal character.

2. CODE MISSING OCCURRED: Cases where time is not preceded by a code word.

3. TIME MISSING OCCURRED: Cases where a code word is not followed by time.

4. CODE LONGER THAN TEN DIGITS OCCURRED: Maximum code word size.

5. NON-SEQUENTIAL TIME OCCURRED: An idiosyncrasy of the recording system whereby erroneous time signals are recorded.

6. TIME GREATER THAN 9999 OCCURRED: The time limit of the internal clock in the DataMyte recorder.

7. INITIAL ENTRY MISSING OCCURRED: "Zero" time not specified in Field #10.

8. LAST CODE NOT 9999 OCCURRED:

9. CODE GREATER THAN MAXIMUM OCCURRED: Specified by the experimenter.

The above corrections remove all erroneous data entry that we have encountered using this system in the reduction of nearly 500 data files (observation periods). Unless it is desirable to retrieve a missing datum no manipulation of a data file is necessary prior to its introduction into the program routine.

II. DATA REDUCTION

This portion of the program reduces the data onto three N x N contingency tables. The first table is a precedes/follows frequency matrix, the second scores time elapsed between all precedes/follows couplets, and the third is a time-delay matrix accumulating time between all possible couplets regardless of their precedes/follows relationship. The following sample will illustrate each matrix.

SAMPLE DATA (5 variables, code words 11 through 15)

12,0000

13,0009

14,0010

11,0013

15,0101

15,0115

15,0136

12,0150

FREQUENCY TABLE

preceding event \ following event	11	12	13	14	15	SUM
11					1	1
12			1			1
13				1		1
14	1					1
15		1			2	3
SUM	1	1	1	1	3	7

The Frequency Table tallies events as they occurred during recording on a precedes/follows contingency table.

TIME TABLE 1

*	11	12	13	14	15	SUM
11					88	88
12			9			9
13				1		1
14	3					3
15		14			35	49
SUM	3	14	9	1	123	150

In Time Table 1 the time elapsed between each precedes/follows event tallied on the previous Frequency Table is shown - useful for latency or time between behavioral events.

TIME TABLE 2

*	11	12	13	14	15	SUM
11		137			88	225
12			9			9
13	4	141		1	92	238
14	3	140			91	234
15		14			35	49
SUM	7	432	9	1	306	755

In Time Table 2 the time elapsed between all possible permutations of couplets regardless of their precedes/follows relationship is shown. Time Table 2 matrix differs from Time Table 1 in many ways. For example, the couplet 12 following 13 was not a sequential event in the Frequency Table or Time Table 1, however, it is a possible permutation of the variables used and the time elapsed between the two was 141 secs. This matrix is useful for "on" and "off" events and in this instance 13 could signal the beginning of some event which might have consisted of events 14, 11, and 15, and 12 signalled the end ("off") of that particular sequence.

It is doubtful that any experimenter would be interested in every value in the three matrices. However, the information is tallied and available if the need arises. The Frequency Table lends itself quickly to the computation of transitional probabilities and other methods of sequence analysis (Slater, 1973). The column or row totals can be easily used in routine statistical analyses such as analysis of variance, regression analysis, etc. Matrices can be created for each observation period or several periods may be accumulated on one set of matrices.

The system does have two disadvantages, 1) two behavioral events cannot be recorded simultaneously, and 2) each "ENTER" command on the keyboard must be followed by a 0.5 sec. interval before another key is depressed. We feel the advantages of the system considerably outweigh the disadvantages.

The entire program is appended.

POTENTIAL USERS

The program is permanently filed with the Mid-Illinois Computer Cooperative (MICC) at Edwardsville, Illinois. Institutions in Illinois that have MICC services may request permission to use the program by writing any one of the authors. The program is available on cassette tape and other formats directly from Electro/General Corporation, 14960 Minnetonka Industrial Road, Minnetonka, Minnesota 55343. Interested persons should write the company directly.

ACKNOWLEDGMENTS

We would like to take this opportunity to acknowledge many who contributed in the development of this material. First, financial assistance for the actual design and writing of the program was supported by Ward's NSF grant GB-30338. Student helpers worked at terminals reducing actual behavioral data which tested various facets of the program and were paid by Ward's Illinois State University Research Grants 74-38 and 75-12. Dr. Kup Tcheng, Director of Academic and Research Consultation, Computer Services, is to be commended for his encouragement in this project and making his staff available for the design and writing of the program. We thank Ken Chow who assisted Richard H. Miller in writing the prototype for the correction portion of the program. The assistance of John F. King, Assistant Research Engineering-Psychology and the services of the Department of Psychology for use of their teletype terminals and their Data General NOVA 820 computer was indispensable in creating the prototype.

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```
00100*****************************COMMENTS*****************************
00110*                                                                *
00120* DATA REDUCTION PROGRAM FOR THE BIOLOGICAL SCIENCES             *
00130*                                                                *
00140* THIS PROGRAM EDITS DATA FILES FROM BIOLOGICAL                  *
00150* EXPERIMENTS.  DATA INCLUDES INTRODUCTORY INFORMATION,          *
00160* BEHAVIOR CODE, AND TIME.  THE DATA IS TESTED FOR THE           *
00170* FOLLOWING ERRORS:                                              *
00180*      ERROR IN THE INTRODUCTORY INFORMATION                     *
00190*      ILLEGAL CHARACTERS OR BLANKS                              *
00200*      MISSING CODES                                             *
00210*      MISSING TIMES                                             *
00220*      CODES LONGER THAN TEN DIGITS                              *
00230*      NON-SEQUENTIAL TIMES                                      *
00240*      TIMES GREATER THAN 9999                                   *
00250*      INITIAL ENTRIES MISSING                                   *
00260*      LAST CODE NOT 9999                                        *
00270*      CODES GREATER THAN MAXIMUM SPECIFIED BY THE USER          *
00280* CONSULT THE WRITE-UP FOR DETAILED INFORMATION                  *
00290* CONCERNING THE ERROR CHECKS.                                   *
00300*                                                                *
00310* ONCE EDITING IS COMPLETED, FREQUENCY TABLES AND TIME           *
00320* TABLES ARE PRINTED OUT.  MORE THAN ONE FILE MAY BE             *
00330* ACCUMULATED INTO THE TABLES.                                   *
00340*                                                                *
00350* PROGRAM REQUESTED BY JACK WARD, PROFESSOR OF BIOLOGICAL        *
00360* SCIENCES, ILLINOIS STATE UNIVERSITY, NORMAL, ILL.              *
00370*                                                                *
00380* PROGRAM DESIGNED AND WRITTEN BY RAMESH CHAUDHARI AND           *
00390* STEVE SKINNER, COMPUTER SERVICES, ILLINOIS STATE.              *
00400*                                                                *
00410* NOTE:  CONTACT THE ABOVE NAMED INDIVIDUALS FOR                 *
00420*        INFORMATION CONCERNING USING THE PROGRAM OR             *
00430*        PROGRAM MODIFICATION                                    *
00440*                                                                *
00450******************************************************************
00460 PROGRAM RMS1(TAPE1,TAPE2,INPUT,OUTPUT,TAPE3)
00470 INTEGER A,B,C,D
00480 INTEGER COMMA,BLANK,ASTR
00490 DIMENSION A(20),B(10),C(10),D(2)
00500 DIMENSION IVAR(9)
00510 DIMENSION IERROR(9)
00520 DATA COMMA,BLANK,NINE,IZERO/1R,,1R ,1R9,1R0/
00530 DATA NCD/99/, NTM/0000/
00540 PRINT,*HOW MANY FILES DO YOU WANT TO ACCUMULATE*,
00550 READ,NFL
00560 PRINT,*WHAT IS THE MAXIMUM CODE*,
00570 READ,MCD
00580 PRINT,*WHAT IS THE MAXIMUM TIME*,
00590 READ,MTM
00600 PRINT,*DO YOU WANT A DATA LIST*,
00610 READ,ILIST
00620 IFL=0
00630 1111 CONTINUE
```

```
00640 DATA IFLG/0/
00650 ISW=0
00660 JSW=0
00670 KNT=0
00680 IFL=IFL+1
00690 PRINT,*WHAT IS THE NAME OF THE NEXT FILE*,
00700 READ, FLN
00710 DO 198 I=1,9
00720 198 IERROR(1)=0
00730 CALL GET(5HTAPE1,FLN,0,0)
00740 1 READ(1,100)A
00750 IF(EOF,1)900,2
00760 2 CONTINUE
00770 IF(ILIST.EQ.3HYES)WRITE(3,1001)A
00780 1001 FORMAT(1H ,20R1)
00790 100 FORMAT(20R1)
00800 DO 5 I=1,20
00810 IS=A(I)
00820 IF(IS.EQ.BLANK.OR.IS.EQ.COMMA.OR.(IS.GE.IZERO.AND.IS.LE.NINE))GO TO
00830 IC=1
00840 GO TO 40
00850 5 CONTINUE
00860 DO 10 I=1,10
00870 IF(A(I).NE.COMMA)GO TO 10
00880 I1=I
00890 GO TO 15
00900 10 CONTINUE
00910 11 IC=1
00920 GO TO 40
00930 15 CONTINUE
00940 IF(I1.LE.11)GO TO 16
00950 IC=4
00960 GO TO 40
00970 16 I2=I1-1
00980 IF(I2.LE.0)GO TO 21
00990 DO 20 I=1,I2
01000 IF(A(I).NE.BLANK)GO TO 25
01010 20 CONTINUE
01020 21 IC=2
01030 GO TO 40
01040 25 I3=I1+1
01050 DO 30 I=I3,20
01060 IF(A(I).EQ.COMMA)GO TO 35
01070 IF(A(I).NE.BLANK)GO TO 45
01080 30 CONTINUE
01090 35 IC=3
01100 40 CONTINUE
01110 IERROR(IC)=IERROR(IC)+1
01120 IF(ILIST.NE.3HYES)GO TO 1
01130 101 FORMAT(1R ,10R1)
01140 GO TO (41,42,43,44),IC
01150 41 WRITE(3,800)
01160 800 FORMAT(40H ---ILLEGAL CHARACTER OR BLANK RECORD---)
01170 GO TO 1
```

```
01180 42 WRITE(3,801)
01190 801 FORMAT(19H ---CODE MISSING---)
01200 GO TO 1
01210 43 WRITE(3,802)
01220 802 FORMAT(19H ---TIME MISSING---)
01230 GO TO 1
01240 44 WRITE(3,803)
01250 803 FORMAT(33H ---CODE LONGER THAN 10 DIGITS---)
01260 GO TO 1
01270 45 CONTINUE
01280 DO 47 I=1,10
01290 B(I)=BLANK
01300 47 C(I)=BLANK
01310 K=10
01320 DO 50 I=1,I2
01330 J=I2-I+1
01340 B(K)=A(J)
01350 50 K=K-1
01360 K=10
01370 DO 55  I=I3,20
01380 J=20-I+I3
01390 IF(A(J).EQ.BLANK)GO TO 55
01400 C(K)=A(J)
01410 K=K-1
01420 55 CONTINUE
01430 ENCODE(20,102,D)B,C
01440 102 FORMAT(20R1)
01450 DECODE(20,103,D)ICD,ITM
01460 103 FORMAT(2I10)
01470 KNT=KNT+1
01480 IF(ICD.EQ.9999)GO TO 998
01490 IF(ICD.LE.MCD.OR.KNT.LT.10)GO TO 197
01500 IF(ILIST.EQ.3HYES)WRITE(3,808)
01510 808 FORMAT(38H---CODE IS GREATER THAN THE MAXIMUM---)
01520 IERROR(9)=IERROR(9)+1
01530  GO TO 1
01540 197 CONTINUE
01550 IF(ITM.LE.MTM.OR.KNT.LE.10)GO TO 210
01560 IF(ILIST.EQ.3HYES)WRITE(3,904)
01565 904 FORMAT(26H ---NON-SEQUENTIAL TIME---)
01570 IERROR(5)=IERROR(5)+1
01580 GO TO 1
01590 210 CONTINUE
01600 IF (KNT.LE.1) GO TO 510
01610 IF(ICD.NE.0)GO TO 200
01620 ISW=1
01630 GO TO 1
01640 200 IF(ITM.NE.0)GO TO 202
01650 JSW=1
01660 GO TO 511
01670 202 IF(JSW.NE.1)GO TO 500
01680 IF(ITM-ITM1)211,211,212
01690 211 IF(ILIST.EQ.3HYES)WRITE(3,804)
01700 804 FORMAT(26H ---NON-SEQUENTIAL TIME---)
```

```
01710 IERROR(5)=IERROR(5)+1
01720 GO TO 1
01730 212 IF(ITM-9999)400,400,215
01740 215 IF(ILIST.EQ.3HYES)WRITE(3,805)
01750 805 FORMAT(29H ---TIME GREATER THAN 9999---)
01760 IERROR(6)=IERROR(6)+1
01770 GO TO 1
01780 400 CONTINUE
01790 IF(ISW.EQ.1)GO TO 520
01800 410 WRITE(2,)ICD,ITM
01810 420 CONTINUE
01820 ICD1=ICD
01830 ITM1=ITM
01840 GO TO 1
01850 500 IF(KNT-10)510,511,511
01860 510 IVAR(KNT)=ICD
01870 GO TO 420
01880 511 WRITE(2,) IVAR
01890 JSW=1
01900 IF(ITM.EQ.0)GO TO 410
01910 WRITE(2,) NCD,NTM
01920 IF(ILIST.EQ.3HYES)WRITE(3,806)
01930 806 FORMAT(28H ---INITIAL ENTRY MISSING---)
01940 IERROR(7)=IERROR(7)+1
01950 GO TO 410
01960 520 ITM=ITM1
01970 ISW=0
01980 GO TO 410
01990 900 IF(ILIST.EQ.3HYES)WRITE(3,807)
02000 807 FORMAT(28H ---LAST CODE IS NOT 9999---)
02010 IERROR(8)=IERROR(8)+1
02020 ICD=9999
02030 998 WRITE(2,)ICD,ITM
02040 CALL RETURN(5HTAPE1)
02050 IF(IFL.EQ.NFL)IFLG=1
02060 REWIND 2
02070 WRITE(3,199)IERROR
02080 199 FORMAT(/* ILLEGAL CHARACTER OR BLANK OCCURRED*,I13/,
02090+* CODE MISSING OCCURRED*,I27/* TIME MISSING OCCURRED*,I27/
02100+* CODE LONGER THAN TEN DIGITS OCCURRED*,I12/
02110+* NON-SEQUENTIAL TIME OCCURRED*,I20/
02120+* TIME GREATER THAN 9999 OCCURRED*,I17/
02130+* INITIAL ENTRY MISSING OCCURRED*,I18/
02140+* LAST CODE NOT 9999 OCCURRED*,I21/
02150+* CODE GREATER THAN THE MAXIMUM OCCURRED*,I10)
02160 CALL RMS2(IFLG)
02170 CALL RETURN(5HTAPE2)
02180 IF(IFLG.EQ.0)GO TO 1111
02190 STOP
02200 END
02210 SUBROUTINE RMS2(IFLG1)
02220 DIMENSION IVC(26),IFR(26,26),ITMI(26,26),ITMII(26,26),IVT(26)
02230 DIMENSION IFLG(25,25),INDX(26)
02240 DATA IFLG/625*1/,INDX/1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,
```

```
02250+17,18,19,20,21,22,23,24,25,26/
02260 DATA IVC/26*0/,IFR,ITMI,ITMII/2028*0/,IVT/26*9999/,N/26/
02270 READ(2,)NV,NS,IMO,IDY,IYR,ITM,ISN,IEXP,IDES
02280 WRITE(3,100)IEXP,IDES,NV,NS,IMO,IDY,IYR,ITM,ISN
02290 100 FORMAT(*1EXPERIMENTER"S ? :*,I7/* DESCRIPTION :*,I12/
02300+* ? OF VARIABLES :*,I9/* ? OF SUBJECTS :*,I10/* DATE AND TIME :*,
02310+I2,1H/,I2,1H/,I4,2X,I4/* MACHINE SER ? :*,I10)
02320 IVC(N)=9999999
02330 READ(2,)I,I
02340  I=NCD+1
02350 IF(I.GT.1)GO TO 11
02360 READ(2,)IVC(1),IT
02370 I=2
02380 11 READ(2,)ICD,IT
02390 IF(ICD.EQ.9999)GO TO 20
02400 I1=I-1
02410 DO 15 J=1,I1
02420 IF(ICD.EQ.IVC(J))GO TO 19
02430 15 CONTINUE
02440 IVC(I)=ICD
02450 I=I+1
02460 19 IF(ENDFILE 1)20,11
02470 20 NCD=I-1
02480 J=J+1
02490 WRITE(3,101)IT
02500 101 FORMAT(* TOTAL EXP TIME  :*,I8,* SECONDS*)
02510 REWIND 2
02520 READ(2,)NV,NS,IMO,IDY,IYR,ITM,ISN,IEXP,IDES
02530 READ(2,)IC,IT
02540 IF(IT.NE.0)WRITE(3,)* INITIAL ENTRY MISSING*
02550 IF(IC.EQ.9999)GO TO 99
02560 READ(2,)IC1,IT1
02570 CALL INDEX(IC1,IVC,NCD,I)
02580 IVT(I)=IT1
02590 111 READ(2,)IC,IT
02600 IF(IC.EQ.9999) GO TO 131
02610 CALL INDEX(IC,IVC,NCD,J)
02620 IFR(I,J)=IFR(I,J)+1
02630 ITMI(I,J)=ITMI(I,J)+IT-IT1
02640 DO 120 K=1,NCD
02650 IF(IVT(K).GE.IT.OR.IFLG(K,J).NE.1)GO TO 120
02660 IFLG(K,J)=0
02670 ITMII(K,J)=ITMII(K,J)+IT-IVT(K)
02680 120 CONTINUE
02690 DO 125 K=1,NCD
02700 125 IFLG(J,K)=1
02710 IVT(J)=IT
02720 IT1=IT
02730 I=J
02740 GO TO 111
02750 131 CONTINUE
02760 IF(IFLG1.EQ.0)RETURN
02770 DO  140 I=1,NCD
02780 DO 140 J=1,NCD
```

```
02790 IFR(I,N)=IFR(I,N)+IFR(I,J)
02800 ITMI(I,N)=ITMI(I,N)+ITMI(I,J)
02810 ITMII(I,N)=ITMII(I,N)+ITMII(I,J)
02820 IFR(N,J)=IFR(N,J)+IFR(I,J)
02830 ITMI(N,J)=ITMI(N,J)+ITMI(I,J)
02840 ITMII(N,J)=ITMII(N,J)+ITMII(I,J)
02850 140 CONTINUE
02860 DO 145 I=1,NCD
02870 IFR(N,N)=IFR(N,N)+IFR(I,N)
02880 ITMI(N,N)=ITMI(N,N)+ITMI(I,N)
02890 ITMII(N,N)=ITMII(N,N)+ITMII(I,N)
02900 145 CONTINUE
02910 146 J=0
02920 DO 150 I=2,NCD
02930 I1=I-1
02940 IF(IVC(I1).LE.IVC(I))GO TO 150
02950 ISAVE=IVC(I1)
02960 IVC(I1)=IVC(I)
02970 IVC(I)=ISAVE
02980 ISAVE=INDX(I1)
02990 INDX(I1)=INDX(I)
03000 INDX(I)=ISAVE
03010 J=J+1
03020 150 CONTINUE
03030 IF(J.GT.0)GO TO 146
03040 CALL PRNTR(1,IFR,NCD,IVC,INDX,N)
03050 CALL PRNTR(2,ITMI,NCD,IVC,INDX,N)
03060 CALL PRNTR(3,ITMII,NCD,IVC,INDX,N)
03070 RETURN
03080 99 WRITE(3,)* NO DATA ON FILE*
03090 RETURN
03100 END
03110 SUBROUTINE INDEX(IC,ICD,N,J)
03120 DIMENSION ICD(26)
03130 DO 10 I=1,N
03140 IF(IC.NE.ICD(I)) GO TO 10
03150 J=I
03160 RETURN
03170 10 CONTINUE
03180 END
03190 SUBROUTINE PRNTR(IRN,ICD,NV,IVC,INDX,N)
03200 DIMENSION ICD(26,26),TTL(6),IVC(26),INDX(26),ITEMP(26,26)
03210 DATA TTL/9HFREQUENCY,5HTABLE,10HTIME TABLE,2H 1,
03220+10HTIME TABLE,2H 2/
03230 DATA BLNK/1H /,SUM/6H   SUM/,BTM/6H  ----/
03240 DO 5 I=1,N
03250 DO 5 J=1,N
03260 5 ITEMP(I,J)=0
03270 DO 10 J=1,N
03280 K=INDX(J)
03290 DO 10 I=1,N
03300 10 ITEMP(I,J)=ICD(I,K)
03310 DO 20 I=1,N
03320 K=INDX(I)
```

```
03330 DO 20 J=1,N
03340 20 ICD(I,J)=ITEMP(K,J)
03350 I=2*IRN-1
03360 WRITE(3,100)TTL(I),TTL(I+1)
03370 100 FORMAT(1H1,2A10)
03380 NT=NV/9+1
03390 J1=1
03400 J2=0
03410 DO 50 K=1,NT
03420 IF(K.EQ.NT)GO TO 40
03430 J2=J1+8
03440 WRITE(3,101)(IVC(J),J=J1,J2)
03450 101 FORMAT(//7H       *,9I6/)
03460 DO 30 I=1,NV
03470 30 WRITE(3,102)IVC(I),(ICD(I,J),J=J1,J2)
03480 WRITE(3,104)(BTM,I=1,9)
03490 WRITE(3,103)(ICD(N,J),J=J1,J2)
03500 J1=J1+9
03510 GO TO 50
03520 40 J1=J2+1
03530 J2=NV
03540 WRITE(3,101)(IVC(I),I=J1,J2)
03550 J=J2-J1+2
03560 WRITE(3,105)(BLNK,I=1,J),SUM
03570 105 FORMAT(1H+,29A6)
03580 IF(J.GT.1)GO TO 43
03590 DO 42 I=J12,J2
03600 42 WRITE(3,102)IVC(I),ICD(I,N)
03610 WRITE(3,104)(BTM,I=1,J)
03620 WRITE(3,103)ICD(N,N)
03630 GO TO 50
03640 43 CONTINUE
03650 DO 45 I=1,NV
03660 45 WRITE(3,102)IVC(I),(ICD(I,J),J=J1,J2),ICD(I,N)
03670 J=J2-J1+2
03680 WRITE(3,104)(BTM,I=1,J)
03690 104 FORMAT(1H ,6X,9A6)
03700 WRITE(3,103)(ICD(N,J),J=J1,J2),ICD(N,N)
03710 103 FORMAT(*    SUM*,9I6)
03720 50 CONTINUE
03730 102 FORMAT(1H ,10I6)
03740 RETURN
03750 END
037600
READY.
```

TRANSACTIONS, ILL. STATE ACAD. SCI.
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THE FIRST RECORD IN ILLINOIS OF BROCHYMENA PUNCTATA PUNCTATA (HEMIPTERA:PENTATOMIDAE)

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ABSTRACT. -- The presence in Illinois of Brochymena punctata punctata is reported.

Brochymena punctata punctata Van Duzee is a rare subspecies, being recorded, thus far, only from Virginia, Georgia, Florida (Ruckes 1946), and Indiana (Blatchley 1926). It feeds on various species of oaks (Quercus) (Ruckes 1946).

Ruckes (1946) stated that this subspecies was apparently restricted to the southeastern United States, and that Blatchley's Indiana specimen "could possibly have been accidentally introduced and escaped as an adventitious individual."

There are presently 5 southern Illinois specimens housed in the Entomology Collection, Zoology Research Museum, SIU-C, that I have determined to be B. p. punctata. These specimens establish the presence of this subspecies in Illinois, and strongly suggest that Blatchley's Indiana specimen was not adventitious but part of a breeding population. Also, this represents the first subspecies of B. punctata to be reported for Illinois.

The label information for the 5 specimens is given below. The 1975 specimens were collected on black walnut (Juglans nigra L.), but not observed feeding.

Gallatin Co., Saline Mines, 8 Aug. 1975, 1 ♂, J. P. Cuda, Coll.
Jackson Co., Carbondale, 19 May 1964, 1 ♂, S. Papaeliou, Coll.; Giant City, 10 May, 1 ♂, 19 May, 1 ♀, 17-20 May 1975, 1 ♂, J. P. Cuda, Coll.

LITERATURE CITED

Blatchley, W. S. 1926. Heteroptera or true bugs of eastern North America with especial reference to the faunas of

Indiana and Florida. Nature Pub. Co., Indianapolis. 1116 pp.

Ruckes, H. 1946. Notes and keys on the genus Brochymena (Pentatomidae, Heteroptera). Entomol. Amer. 26:143-238.

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NOTES ON THE DIATOM FLORA OF LAKE AND MCHENRY COUNTIES, ILLINOIS

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This paper lists seventy-two diatom species in the algal flora of Lake and McHenry Counties, of which fifty-eight are new records for McHenry County and thirty-nine for Lake County.

In the past few years, papers by Grady (1974) and Lipsey (1975) have added a number of taxa to the diatom flora of Illinois. Yet, for the most part, the recording of the Illinois diatom flora has been minimal and incomplete.

To date, forty-seven species of algae have been reported from McHenry County (Britton, 1944) and one hundred sixty-one from Lake County (Britton, 1944; Tiffany and Britton, 1952; Grady, 1974). The diatom flora of McHenry County is poorly known with but a single, apparent, published record, Melosira granulata (Britton, 1944). Lake County now contains slightly more than thirty species in the published literature (Britton, 1944; Grady, 1974). With the species listed in the present report, the total number of algal species, including their varieties, for McHenry and Lake Counties now stands at one hundred five and two hundred, respectively.

The following records were obtained from collections made under the direction of Jerrold H. Zar for a Federal Highway Administration environmental impact statement, supported by the Illinois Department of Transportation.

ANNOTATED CHECKLIST

Nomenclature in this list follows that of Hustedt (1930), Tiffany and Britton (1952), Cleve-Euler (1951-1955), Patrick and Reimer (1966), and Stoermer and Yang (1969). In each citation, the county in which the collection was made is indicated in upper case, followed by the collection locale(s) and month of sampling.

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[1]Address after January 1, 1977: Department of Botany, Southern Illinois University at Carbondale, Carbondale, Illinois 62901.

CHRYSOPHYTA
BACILLARIOPHYCEAE

Centrales

Melosira ambigua (Grun.) O. Mull. LAKE: Marsh west of U.S. Route 12 - Illinois Route 59, between Brandenburg Road and Sullivan Lake Road, September 1974; Squaw Creek at Illinois Route 120 (Belvidere Road), September 1974; Unnamed stream on Nippersink Road, flowing between Wooster Lake and Fish Lake, September 1974; Volo Bog drain at Sullivan Lake Road, September 1974. MCHENRY: Lily Lake drain at Sullivan Lake Road, September 1974; Dutch Creek at Illinois Route 31, September 1974; Nippersink Creek east of Keystone Road, October 1974; Small creek entering Nippersink Creek from the west and paralleling Northern Pump Company farm entrance road east from Keystone Road, October 1974.

M. granulata var. angustissima Mull. LAKE: Unnamed stream on Nippersink Road, flowing between Wooster Lake and Fish Lake, September 1974; Volo Bog drain at Sullivan Lake Road, September 1974. MCHENRY: Nippersink Creek east of Keystone Road, October 1974.

M. varians C. A. Ag. LAKE: Wilson Bog drain at Sullivan Lake Road, September 1974. MCHENRY: Lily Lake drain at Sullivan Lake Road, September 1974; Dutch Creek at Illinois Route 31, September 1974.

Cyclotella Meneghiniana Kutz. LAKE: Marsh west of U. S. Route 12 - Illinois Route 59, between Brandenburg Road and Sullivan Lake Road, September 1974; Squaw Creek at Illinois Route 120 (Belvidere Road), September 1974; Unnamed stream on Nippersink Road, flowing between Wooster Lake and Fish Lake, September 1974; Volo Bog drain at Sullivan Lake Road, September 1974. MCHENRY: Lily Lake drain at Sullivan Lake Road, September 1974; Dutch Creek at Illinois Route 31, September 1974; Nippersink Creek east of Keystone Road, October 1974; North branch of Nippersink Creek at Illinois Route 173, October 1974; North-south drain into Nippersink Creek where it crosses Grove Road, October 1974.

Stephanodiscus minutus Grun. ex Cleve and Mull. LAKE: Unnamed stream on Nippersink Road, flowing between Wooster Lake and Fish Lake, September 1974. MCHENRY: Nippersink Creek east of Keystone Road, October 1974.

S. niagarae Ehrenberg. MCHENRY: Lily Lake drain at Sullivan Lake Road, September 1974; Dutch Creek at Illinois Route 31, September 1974; Nippersink Creek east of Keystone Road, October 1974.

Pennales

Diatoma vulgare Bory var. vulgare. MCHENRY: Nippersink Creek east of Keystone Road, October 1974.

Fragilaria brevistriata Grun. var. brevistriata. LAKE: Squaw Creek at Illinois Route 120 (Belvidere Road), September 1974. MCHENRY: Lily Lake drain at Sullivan Lake Road, September 1974.

F. construens (Ehr.) Grun. var. construens. LAKE: Unnamed stream on Nippersink Road, flowing between Wooster Lake and Fish Lake, September 1974.

F. leptostauron (Ehr.) Hust. var. leptostauron. LAKE: Squaw Creek at Nippersink Road, September 1974.

Synedra acus Kutz. var. acus. MCHENRY: Lily Lake drain at Sullivan Lake Road, September 1974.

S. delicatissima W. Sm. var. delicatissima. MCHENRY: Lily Lake drain at Sullivan Lake Road, September 1974; Marsh at south end of Ridgeway Road, October 1974.

S. delicatissima var. angustissima Grun. MCHENRY: Nippersink Creek east of Keystone Road, October 1974.

S. ulna (Nitz.) Ehr. var. ulna. MCHENRY: Small creek entering Nippersink Creek from west and paralleling Northern Pump Company farm entrance road east from Keystone Road, October 1974.

Eunotia curvata (Kutz.) Lagerst. var. curvata. LAKE: Marsh west of U.S. Route 12 - Illinois Route 59, between Brandenburg Road and Sullivan Lake Road, September 1974. MCHENRY: Wilson Bog drain at Illinois Route 134, September 1974; Marsh at south end of Ridgeway Road, October 1974.

Achnanthes exigua var. constricta (Grun.) Hust. LAKE: Volo Bog drain at Sullivan Lake Road, September 1974.

A. hungarica (Grun.) Grun. var. hungarica. LAKE: Volo Bog drain at Sullivan Lake Road, September, 1974. MCHENRY: Wilson Bog drain at Illinois Route 134, September 1974.

A. lanceolata (Breb.) Grun. var. lanceolata. LAKE: Marsh west of U.S. Route 12 - Illinois Route 59, between Brandenburg Road and Sullivan Lake Road, September 1974; Squaw Creek at Illinois Route 120 (Belvidere Road), September 1974. MCHENRY: Lily Lake drain at Sullivan Lake Road, September 1974; Dutch Creek at Illinois Route 31, September 1974; Marsh at south end of Ridgeway Road, October 1974.

A. microcephala (Kutz.) Grun. var. microcephala. LAKE: Volo Bog drain at Sullivan Lake Road, September 1974. MCHENRY: Dutch Creek at Illinois Route 31, September 1974; Small creek entering Nippersink Creek from west and paralleling Northern Pump Company farm entrance road east from Keystone Road, October 1974.

Cocconeis pediculus Ehr. var. pediculus. LAKE: Unnamed stream on Nippersink Road, flowing between Wooster Lake and Fish Lake, September 1974. MCHENRY: Nippersink Creek east of Keystone Road, October 1974; Small creek entering Nippersink Creek from west and paralleling Northern Pump Company farm entrance road east from Keystone Road, October 1974; North branch of Nippersink Creek at Illinois Route 173, October 1974.

C. placentula var. lineata (Ehr.) V.H. MCHENRY: Lily Lake drain at Sullivan Lake Road, September 1974; Dutch Creek at Illinois Route 31, September 1974; Small creek entering Nippersink Creek from west and paralleling Northern Pump Company farm entrance road east from Keystone Road, October 1974; North branch of Nippersink Creek at Illinois Route 173, October 1974; North-south drain into Nippersink Creek where it crosses Grove Road, October 1974.

Rhoicosphenia curvata (Kutz.) Grun. ex Rabh. var. curvata. MCHENRY: Small creek entering Nippersink Creek from west and paralleling Northern Pump Company farm entrance road east from Keystone Road, October 1974; North-south drain into Nippersink Creek where it crosses Grove Road, October 1974.

Caloneis lewisii var. inflata (Schultze) Patr. comb. nov. LAKE: Squaw Creek at Illinois Route 120 (Belvidere Road), September 1974. MCHENRY: Small creek entering Nippersink Creek from west and paralleling Northern Pump Company farm entrance road east from Keystone Road, October 1974.

Gyrosigma acuminatum (Kutz.) Rabh. var. acuminatum. LAKE: Squaw Creek at Nippersink Road, September 1974.

G. attenuatum (Kutz.) Rabh. var. attenuatum. MCHENRY: North branch of Nippersink Creek at Illinois Route 173, October 1974.

G. scalproides (Rabh.) Cl. var. scalproides. LAKE: Squaw Creek at Illinois Route 120 (Belvidere Road), September 1974.

G. sciotense (Sulliv. & Wormley) Cl. var. sciotense. LAKE: Squaw Creek at Illinois Route 120 (Belvidere Road), September 1974.

Navicula capitata Ehr. var. capitata. LAKE: Squaw Creek at Illinois Route 120 (Belvidere Road), September 1974. MCHENRY: Lily Lake drain at Sullivan Lake Road, September 1974; Dutch Creek at Illinois Route 31, September 1974; Small creek entering Nippersink Creek from west and paralleling Northern Pump Company farm entrance road east from Keystone Road, October 1974; North-south drain into Nippersink Creek where it crosses Grove Road, October 1974.

N. cryptocephala Kutz. var. cryptocephala. LAKE: Marsh west of U.S. Route 12 - Illinois Route 59, between Brandenburg Road and Sullivan Lake Road, September 1974; Squaw Creek at Illinois Route 120 (Belvidere Road), September 1974; Unnamed stream on Nippersink Road, flowing between Wooster Lake and Fish Lake, September 1974;

Volo Bog drain at Sullivan Lake Road, September 1974; Squaw Creek at Nippersink Road, September 1974. MCHENRY: Wilson Bog drain at Illinois Route 134, September 1974; Lily Lake drain at Sullivan Lake Road, September 1974; Dutch Creek at Illinois Route 31, September 1974; Marsh at south end of Ridgeway Road, October 1974; Small creek entering Nippersink Creek from west and paralleling Northern Pump Company farm entrance road east from Keystone Road, October 1974; North branch of Nippersink Creek at Illinois Route 173, October 1974; North-south drain into Nippersink Creek where it crosses Grove Road, October 1974.

N. cryptocephala var. veneta (Kutz.) Rabh. LAKE: Squaw Creek at Illinois Route 120 (Belvidere Road), September 1974. MCHENRY: Dutch Creek at Illinois Route 31, September 1974; North-south drain into Nippersink Creek where it crosses Grove Road, October 1974.

N. decussis Østr. var. decussis. LAKE: Unnamed stream on Nippersink Road, flowing between Wooster Lake and Fish Lake, September 1974. MCHENRY: North branch of Nippersink Creek at Illinois Route 173, October 1974.

N. gottlandica Grun. var. gottlandica. LAKE: Marsh west of U.S. Route 12 - Illinois Route 59, between Brandenburg Road and Sullivan Lake Road, September 1974; Volo Bog drain at Sullivan Lake Road, September 1974. MCHENRY: Marsh at south end of Ridgeway Road, October 1974.

N. graciloides A. Mayer var. graciloides. LAKE: Marsh west of U.S. Route 12 - Illinois Route 59, between Brandenburg Road and Sullivan Lake Road, September 1974; Squaw Creek at Illinois Route 120 (Belvidere Road), September 1974; Unnamed stream on Nippersink Road, flowing between Wooster Lake and Fish Lake, September 1974; Volo Bog drain at Sullivan Lake Road, 1974; Squaw Creek at Nippersink Road, September 1974. MCHENRY: Dutch Creek at Illinois Route 31, September 1974; Nippersink Creek east of Keystone Road, October 1974; North branch of Nippersink Creek at Illinois Route 173, October 1974; North-south drain into Nippersink Creek where it crosses Grove Road, October 1974.

N. heufleri var. leptocephala (Breb. ex Grun.) Patr. comb. nov. MCHENRY: Marsh at south end of Ridgeway Road, October 1974.

N. minima Grun. var. minima. MCHENRY: Marsh at south end of Ridgeway Road, October 1974.

N. muralis Grun. var. muralis. MCHENRY: Marsh at south end of Ridgeway Road, October 1974.

N. mutica var. tropica Hust. MCHENRY: Nippersink Creek east of Keystone Road, October 1974.

N. pupula Kutz. var. pupula. MCHENRY: Dutch Creek at Illinois Route 31, September 1974; Small creek entering Nippersink Creek from

west and paralleling Northern Pump Company farm entrance road east from Keystone Road, October 1974.

N. rhynchocephala Kutz. var. rhychocephala. MCHENRY: Dutch Creek at Illinois Route 31, September 1974; Small creek entering Nippersink Creek from west and paralleling Northern Pump Company farm entrance road east from Keystone Road, October 1974, October 1974; North branch of Nippersink Creek at Illinois Route 173, October 1974.

N. seminulum var. hustedtii Patr. MCHENRY: Marsh at south end of Ridgeway Road, October 1974.

N. tripunctata (O.F. Mull.) Bory var. tripunctata. MCHENRY: Small creek entering Nippersink Creek from west and paralleling Northern Pump Company farm entrance road east from Keystone Road, October 1974.

N. tripunctata var. schizonemoides (V.H.) Patr. MCHENRY: Lily Lake drain at Sullivan Lake Road, September 1974.

N. viridula (Kutz.) emend. V.H., var. viridula. MCHENRY: North branch of Nippersink Creek at Illinois Route 173, October 1974; North-south drain into Nippersink Creek where it crosses Grove Road, October 1974.

Pinnularia braunii var. amphicephala (A. Mayer) Hust. MCHENRY: Marsh at south end of Ridgeway Road, October 1974.

P. microstauron (Ehr.) Cl. var. microstauron. MCHENRY: Wilson Bog drain at Illinois Route 134, September 1974.

Stauroneis obtusa Lagerst. var. obtusa. LAKE: Marsh west of U.S. Route 12 - Illinois Route 59, between Brandenburg Road and Sullivan Lake Road, September 1974.

Gomphonema acuminatum Ehr. MCHENRY: Wilson Bog drain at Illinois Route 134, September 1974.

G. constrictum Ehr. MCHENRY: Wilson Bog drain at Illinois Route 134, September 1974.

G. olivaceum (Lyngbye) Kutz. LAKE: Unnamed stream on Nippersink Road, flowing between Wooster Lake and Fish Lake, September 1974. MCHENRY: Marsh at south end of Ridgeway Road, October 1974; Nippersink Creek east of Keystone Road, October 1974.

G. parvulum (Kutz.) Grunow. LAKE: Squaw Creek at Illinois Route 120 (Belvidere Road), September 1974; Unnamed stream on Nippersink Road, flowing between Wooster Lake and Fish Lake, September 1974; Volo Bog drain at Sullivan Lake Road, September 1974. MCHENRY: Lily Lake drain at Sullivan Lake Road, September 1974; Dutch Creek at Illinois Route 31, September 1974; Nippersink Creek east of Keystone Road, October 1974; Small creek entering Nippersink Creek from west and paralleling Northern Pump Company farm entrance road east from

Keystone Road, October 1974; North branch of Nippersink Creek at Illinois Route 173, October 1974; North-south drain into Nippersink Creek where it crosses Grove Road, October 1974.

G. parvulum var. genuinum Mayer. LAKE: Marsh west of U.S. Route 12 - Illinois Route 59, between Brandenburg Road and Sullivan Lake Road, September 1974.

Amphora ovalis Kutz. LAKE: Marsh west of U.S. Route 12 - Illinois Route 59, between Brandenburg Road and Sullivan Lake Road, September 1974; Squaw Creek at Illinois Route 120 (Belvidere Road), September 1974. MCHENRY: Wilson Bog Drain at Illinois Route 134, September 1974; Nippersink Creek east of Keystone Road, October 1974; North branch of Nippersink Creek at Illinois Route 173, October 1974.

A. ovalis var. pediculus Kutz. MCHENRY: Small creek entering Nippersink Creek from west and paralleling Northern Pump Company farm entrance road east from Keystone Road, October 1974.

Cymbella affinis Kutz. MCHENRY: North-south drain into Nippersink Creek where it crosses Grove Road, October 1974.

C. Ehrenbergii Kutz. LAKE: Squaw Creek at Illinois Route 120 (Belvidere Road), September 1974.

C. turgida (Gregory) Cleve. LAKE: Marsh west of U.S. Route 12 - Illinois Route 59, between Brandenburg Road and Sullivan Lake Road, September 1974.

Rhopalodia gibba (Ehr.) O. Mull. MCHENRY: Wilson Bog drain at Illinois Route 134, September 1974.

Nitzschia acicularis W. Smith. LAKE: Squaw Creek at Illinois Route 120 (Belvidere Road), September 1974. MCHENRY: Lily Lake drain at Sullivan Lake Road, September 1974; Small creek entering Nippersink Creek from west and paralleling Northern Pump Company farm entrance road east from Keystone Road, October 1974; North-south drain into Nippersink Creek where it crosses Grove Road, October 1974.

N. acuta Hantzsch. MCHENRY: Lily Lake drain at Sullivan Lake Road, September 1974; North-south drain into Nippersink Creek where it crosses Grove Road, October 1974.

N. amphibia Grun. LAKE: Unnamed stream on Nippersink Road, flowing between Wooster Lake and Fish Lake, September 1974. MCHENRY: Wilson Bog drain at Illinois Route 134, September 1974.

N. amphibia var. intermedia Mayer. MCHENRY: Nippersink Creek east of Keystone Road, October 1974.

N. latestriata (Østr.) A. Cl. LAKE: Squaw Creek at Nippersink Road, September 1974.

N. linearis W. Smith. MCHENRY: Lily Lake drain at Sullivan Lake Road, September 1974; Dutch Creek at Illinois Route 31, September 1974; Small creek entering Nippersink Creek from west and paralleling Northern Pump Company farm entrance road east from Keystone Road, October 1974; North-south drain into Nippersink Creek where it crosses Grove Road, October 1974.

N. palea (Kutz.) W. Smith. LAKE: Marsh west of U. S. Route 12 - Illinois Route 59, between Brandenburg Road and Sullivan Lake Road, September 1974; Squaw Creek at Illinois Route 120 (Belvidere Road), September 1974; Unnamed stream on Nippersink Road, flowing between Wooster Lake and Fish Lake, September 1974; Volo Bog drain at Sullivan Lake Road, September 1974. MCHENRY: Wilson Bog drain at Illinois Route 134, September 1974; Lily Lake drain at Sullivan Lake Road, September 1974; Marsh at south end of Ridgeway Road, October 1974; Small creek entering Nippersink Creek from west and paralleling Northern Pump Company farm entrance road east from Keystone Road, October 1974; North branch of Nippersink Creek at Illinois Route 173, October 1974; North-south drain into Nippersink Creek where it crosses Grove Road, October 1974.

N. sigmoidea (Ehr.) W. Smith. LAKE: Squaw Creek at Illinois Route 120 (Belvidere Road), September 1974.

N. vermicularis (Kutz.) Grun. MCHENRY: Dutch Creek at Illinois Route 31, September 1974; Small creek entering Nippersink Creek from west and paralleling Northern Pump Company farm entrance road east from Keystone Road, October 1974; North branch of Nippersink Creek at Illinois Route 173, October 1974; North-south drain into Nippersink Creek where it crosses Grove Road, October 1974.

Cymatopleura elliptica (Brebisson) W. Smith. LAKE: Squaw Creek at Illinois Route 120 (Belvidere Road), September 1974.

C. solea (Brebisson) W. Smith. LAKE: Squaw Creek at Illinois Route 120 (Belvidere Road), September 1974. MCHENRY: Lily Lake drain at Sullivan Lake Road, September 1974.

Surirella ovata Kutz. LAKE: Squaw Creek at Illinois Route 120 (Belvidere Road), September 1974. MCHENRY: Dutch Creek at Illinois Route 31, September 1974; Small creek entering Nippersink Creek from west and paralleling Northern Pump Company farm entrance road east from Keystone Road, October 1974; North-south drain into Nippersink Creek where it crosses Grove Road, October 1974.

S. ovata var. crumena (Brebisson) van Heurck. MCHENRY: Nippersink Creek east of Keystone Road, October 1974.

S. robusta var. splendida (Ehr.) van Heurck. MCHENRY: Dutch Creek at Illinois Route 31, September 1974.

S. spiralis Kutz. LAKE: Squaw Creek at Illinois Route 120 (Belvidere Road), September 1974.

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UPPER LETHAL TEMPERATURES AND EFFECTS OF ACCLIMATION IN NAIADS OF THE DRAGONFLY, PLATHEMIS LYDIA (ODONATA : LIBELLULIDAE)

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ABSTRACT

The upper lethal temperatures of the dragonfly naiad Plathemis lydia (Drury) were measured. Naiads acclimated to temperatures of 5, 20 ± 4, and 36 ± 2 deg Centigrade, were determined to have an LT_{50} of 41.7 deg, and 43.2 deg respectively. Mortality differences at 42 deg C and 43 deg C among acclimated groups were significant at the 1% and 0.1% levels.

The mechanism of temperature relations in ectotherms have been reviewed by Prosser (1973) and Wieser (1973). Thermal acclimation in ectothermic animals is now considered to be characterized by an increased capacity to carry on steady state physiological processes at modified temperatures. Temperature compensation and concomitant metabolic shifts are accomplished by the selective induction of isozymes, changes in ion distribution, and membrane alterations. Isozyme induction consists of the activation and serial synthesis of multiple forms of a particular enzyme, each enzymatic form having a characteristic K_M value with an optimum activity at a determinant temperature (Hochachka, 1973). A plot of K_M versus temperature for an acclimated ectotherm goes through a minimum (maximum substrate affinity) at a point that correlates with the acclimation temperature, and reflects the mobilization of a specific isozyme (Baldwin and Hochachka, 1970; Newell, 1973). The mechanism thus compensates for the normal Q_{10} effect on kinetic activity, and over certain ranges the Q_{10}

may approach 1.0 (Prosser, 1973).

Compensation to temperature extremes can involve short term changes which result in an increasing tolerance for previously lethal temperatures. The shift in lethal thresholds is referred to as resistance acclimation by Prosser (1967, 1973) and has been readily shown for several species of fish (Fry and Hochachka, 1970). Information on the thermal responses of many vertebrates and invertebrates has been published (Whittow, 1970), and it is apparent that research on aquatic ectotherms, with the exception of fish and crustaceans, has concentrated on littoral animals. Fresh water invertebrates have received less attention, although in temperate climates these animals are typically exposed to wide fluctuations in temperature. Larval stages of many insects, for example, may spend years in small ponds and streams which are characterized by considerable variations in temperature. The biology of these animals can be better understood if the mechanisms that allow temperature adaptation are known. The purpose of the present study was to ascertain the upper lethal temperature for naiads of the dragonfly, Plathemis lydia (Drury), an aquatic species that is locally abundant in Illinois and for which no previous temperature data exist. The effects of warm and cold acclimation on the upper lethal temperature were also investigated.

MATERIALS AND METHODS

Dragonfly naiads were collected during September, October and November, 1975, from a small farm pond 6 km south of Carlinville, Illinois (Macoupin County). The pond is located in a forested area and is partially shaded most of the day. Insects were collected by dredging the bottom sediment with a dip net and rinsing the mud from the detritus. The highest naiad density was found two to three meters from shore in water one-half to one meter deep. The water temperature at these spots was 23 - 24 deg C in early September, 16 deg C in early November, and 4 deg C by December 1st, 1975. Approximately 500 insects were collected and sorted at the laboratory in porcelain trays. Only the naiads of P. lydia were retained for study. This species is very common and widely distributed in the United States and Canada (Needham, 1955). The specimens ranged between 8 and 27 mm in length, measured from the labial crenulations to the apex of the inferior caudal appendages. However, only insects between 10 and 18 mm long were used for upper lethal temperature determinations.

The naiads were kept in plastic containers of pond water placed in constant temperature cabinets

(Hythermco, Model 555210) adjusted to the desired temperature. One group of animals was maintained at 20 deg C, which reflects the water temperature at which they were found. A second group was cooled slowly to 5 deg C and maintained at this temperature for 8 days before testing. A third group was kept at 36 deg C for 3½ days and then tested.

The apparatus used to determine upper lethal temperatures consisted of large glass bowls containing pond water which were placed in constant temperature water baths (Fisher, Model 131, and P/S Co., Model 83). Transparent plastic plates covered the bowls and mercury thermometers were inserted through holes drilled in the plates. Once the temperature of the pond water stabilized, it could be kept within plus or minus 0.2 deg C. The bottom of each bowl was provided with a filter paper substrate to which the naiads could cling.

Insects were tested for thermal resistance at a range of temperatures established in preliminary tests as including the upper lethal point. Time of exposure was one hour. Ten individuals were selected at random from one of the groups and placed directly into a previously prepared water bath. Exposing organisms to experimental temperatures in this way characterizes a step function (Clarke, 1967), and is distinguished from a ramp function characterized by a gradual rise in temperature. After 60 minutes all animals were transferred to clean bowls of pond water at 20 deg C for recovery, and were tested for loss of irritability by touching the anal aperture with a probe. This method was determined to be the most reliable way of confirming death in individual specimens. At 12 and 48 hours after treatment, the naiads were inspected again. A recovery period of 48 hours was chosen because animals stressed by the experimental conditions would either die or recover completely within two days. Control groups of untreated naiads showed no mortality during this period.

The naiads used in this study included several different larval instars. The naiads selected for use, however, were chosen over a range of sizes representing a discrete age class. The insects were denied food throughout the testing period as feeding has been shown to affect lethal temperature determinations (Cloudsley-Thompson, 1970; Wieser, 1973). The temperature cabinets were kept dark to reduce the effects of photoperiod which has been shown to affect the metabolic activity of *P. lydia* (Shepard and Lutz, 1976).

RESULTS AND DISCUSSION

Upper lethal temperature determinations are summarized in Table 1. The results show a fairly narrow thermal range in which heat deaths occur, particularly for those insects acclimated to warmer temperatures. Naiads could tolerate exposure to temperatures of 41 or 42 deg C for one hour but could not withstand a temperature of 44 deg C. The increase in percentage mortality is particularly sharp between 42.5 and 43 deg C for naiads acclimated to 20 deg C, and between 43 and 43.5 deg C for naiads acclimated to 36 deg C (Fig. 1). Similar results have been shown for other insects, including Tenebrio molitor and Periplaneta americana (Richards, 1956, 1964) as well as for other invertebrates. Spoor (1955) found that the crayfish, Orconectes rusticus , could survive at least 10 days at 35 deg C but only 24 hours at 35.6 deg C. Orr (1955), working with several species of marine ectotherms, has also found a sharply delineated time of exposure beyond which recovery from heat coma would not occur. With regard to the thermal death points of annelids and molluscs, Bullard (1964) has stated that metabolic reaction rates in adapted animals can fall steeply at temperatures close to the upper and lower lethal limits of the organisms. These observations on P. lydia and other ectotherms may reflect the sudden breakdown of an important physiological process at a certain temperature with a subsequent lethal interuption of body functions. The breakdown would occur when rapid adaptive mechanisms are no longer able to cope with changing temperatures.

The thermal death curves are shown in Figure 1. Percentage mortality values from Table 1 are plotted against the experimental temperatures for all three acclimation groups. It should be noted that the curves from which the LT_{50} values (Cloudsley-Thompson, 1970) have been taken are determined by only two points. The values, 41.7, 42.7 and 43.2 deg C for naiads acclimated to 5, 20 and 36 deg C respectively, suggest a slight change in temperature tolerance after acclimation. The difference is not great, however, and would be of limited value to an organism under stress. Experiments by Whitney (1939) on the mayfly naiad, Baetis rhoda, produced similar results. Exposure of mayflies to high temperatures for 40 hours did not result in a significantly higher heat tolerance for this species. Spoor (1955) found a gain of only one degree in the LT_{50} of crayfish acclimated at 30 deg C for one week. In contrast, work collected by Prosser (1973) on various aquatic ectotherms indicates that resistance adaptation can produce a lethal threshold shift of several degrees

Table 1. Survivorship of Plathemis lydia naiads at high temperatures. Values in parentheses indicate the results of individual trials.

Acclimation Temperature (deg C)	Test Temperature (deg C)	Number of Tests	Number of Naiads	Survivorship	
				Number Surviving	Percent Mortality
	41	1	10	10	0
20	41.5	1	10	9	10
	42	4	40	37	7.5
	42.5	3	30	24 (5,9,10)	20
	43	3	30	4 (0,0,4)	86.7
	44	2	20	0	100
	41	3	30	22 (9,6,7)	26.7
5	42	3	30	12 (6,3,3)	61.3
	43	2	20	0	100
	42	2	20	20	0
	43	3	30	20 (6,6,8)	33.3
36	43.5	2	20	2 (2,0)	90
	44	2	20	0	100
	45	1	10	0	100

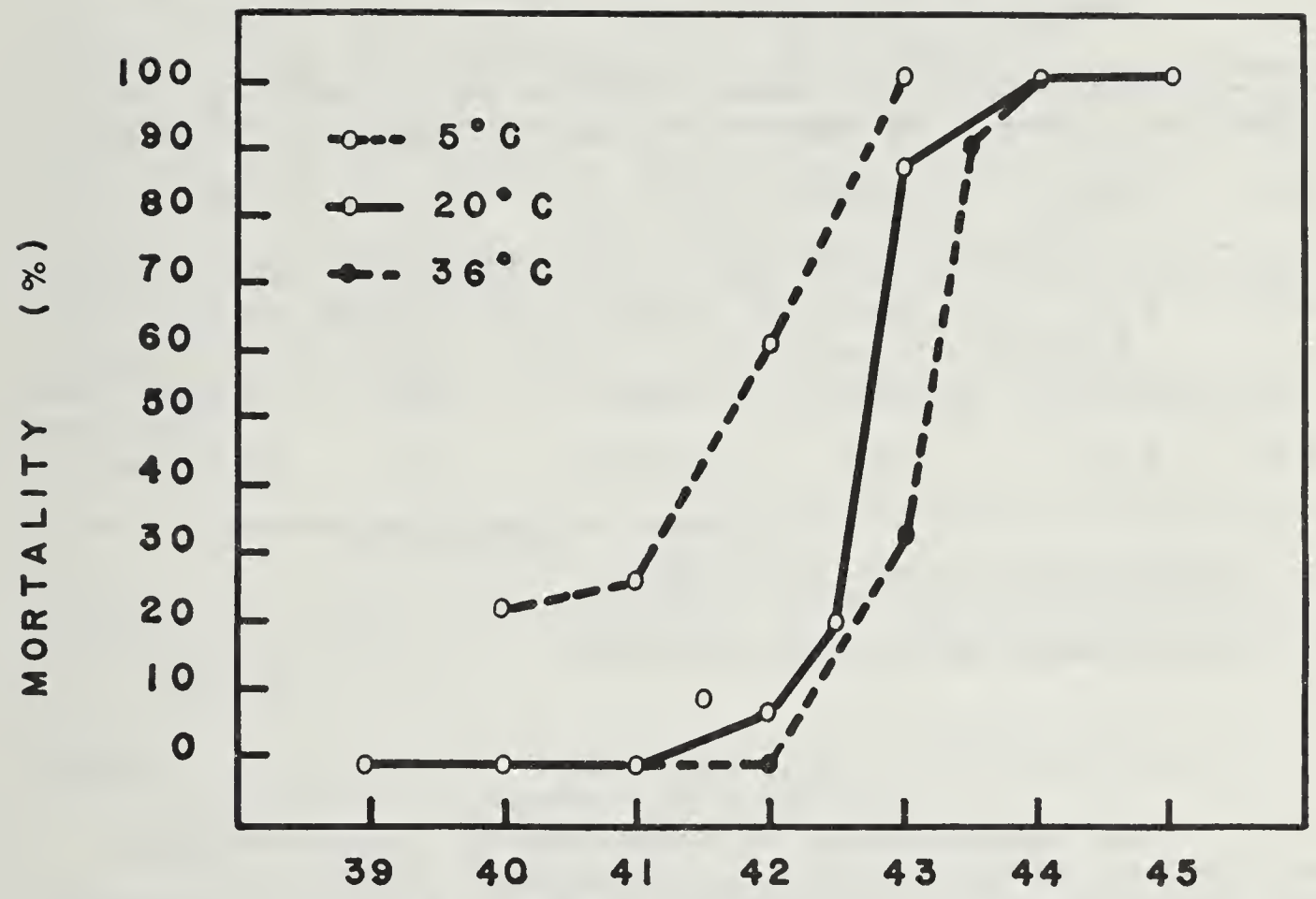

Fig. 1. Mortality of Plathemis lydia naiads acclimated to 20, 5 and 36 deg C, at various temperatures.

in some animals, particularly fish and intertidal gastropods. Grant (1953), has also found a 0.3 deg C gain of heat tolerance in the earthworm Pheretime hupeiensis for every one deg C rise in acclimation temperature.

Chi square analysis of the mortality figures from Table 1 indicate that the difference in temperature tolerance for acclimated groups was most significant at 42 and 43 deg C (Table 2). The lethal temperature point of the group acclimated at 20 deg C lies between these two values.

Table 2. Chi square values of thermal death mortality in Plathemis lydia. The acclimated groups are contrasted at three temperatures. Temperatures are given in deg C.

20 deg vs. 5 deg		20 deg vs. 36 deg		5 deg vs. 36 deg	
T°	X^2	T°	X^2	T°	X^2
41	2.13	41	0.00	41	2.13
42	9.70*	42	0.12	42	9.82*
43	1.33	43	64.00**	43	66.66**

* Significant at the $p < 0.01$

** Significant at the $p < 0.001$

The temperatures to which the P. lydia naiads were exposed do not duplicate conditions expected in their environment. It is unlikely that the pond in which they were found warms beyond 25 deg C. And when heated, naiads would probably seek the cooler areas of the pond. Moore (1955), however, has collected fairy shrimp in ditch water at 42 deg C, a temperature close to the upper lethal point of 44.5 deg C. Organisms living in shallow stationary pools must undoubtedly be exposed to considerable warming during summer months, and those capable of tolerating extreme temperatures have a selective advantage. Under laboratory conditions, P. lydia naiads surrived at least two weeks at 35 deg C with no apparent deleterious effects. As these insects must overwinter in water close to freezing, they are capable of a wide range of thermal tolerance. Tolerance of high temperatures in the laboratory, however, should not imply adaptation to these regimes in a natural environment (Reid, 1967). It is the capacity to compensate for temperatures that an organism may actually experience that has survival value. It has not been established that acclimation effects compensation to temperature extremes although they may occur together (Precht, 1958). However, acclimation need not alter vulnerability to extreme temperatures if the normal compensation range is wide. Data from this experiment indicate that the aquatic stage of Plathemis lydia can tolerate a wide range of

temperatures (Table 1) and can show a small, but significant shift in the upper lethal temperature under thermal stress. The magnitude of this shift, however, does not approach the 4 to 5 degree C shifts in upper lethal temperatures that have been reported for other aquatic arthropods as a result of warm and cold acclimation (Altman and Dittmer, 1973; Barkes, 1959; Newell, 1966, 1973; Prosser, 1973; Vernberg and Vernberg, 1970; Wieser, 1973). This suggests that Plathemis naiads may utilize other thermal compensatory mechanisms such as supercooling (Cloudsley-Thompson, 1970) in addition to thermal acclimation in order to adjust to changing environmental regimes.

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A REVIEW OF SUPPOSED INSECT CATCHING BY BASKING GRAPTEMYS GEOGRAPHICA

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ABSTRACT

The observation by Cahn (1937) of insect catching by basking Graptemys geographica is questioned. New interpretations of the behavior probably witnessed by Cahn are suggested.

Cahn (1937) states that basking map turtles, Graptemys geographica, "may be seen snapping at passing insects, many of which they succeed in catching". Other biologists who have studied this turtle, however, have not mentioned this behavior (Conant, 1938; Everman and Clark, 1916; Garman, 1890; Hay, 1892; Lagler, 1943; Newman, 1906; Penn, 1950), and their findings indicate a strictly aquatic diet with food always being swallowed underwater (Ernst and Barbour, 1972). My observations on the basking behavior of this species in the Illinois River may explain this contradiction. Basking G. geographica were often observed making quick, jerky, forward and lateral motions of the head and neck which from a distance could easily be interpreted as insect catching behavior (in fact, at first observation of this phenomenon I thought Cahn's unusual observations were upheld). Closer observation of many basking map turtles over several days, however, (from a make-shift blind approximately 10 m from the basking site and with the aid of 7x50 binoculars) confirmed that in all cases the head and neck movements were made with the mouth closed, and therefore could not be feeding behavior. If this is indeed the behavior Cahn observed, a more likely explanation for the head jerking motions may be the dislodgement of annoying flies and other insects (which could be seen crawling on the basking turtles) or simply the easing of muscular kinks incurred by maintaining position on basking logs for hours. The presence of terrestrial insects in the digestive tracts of many G. geographica may be explained by my observation of these turtles' eating of drowned insects floating on the water surface.

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THE REACTION OF PHENYLLITHIUM AND $CsGeCl_3$[1]

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ABSTRACT

The title reaction has been studied in some detail. Attempts have been made to reconcile the observed products tetraphenylgermane, biphenyl, and a solid (polymer?) with published reaction schemes. The nature of reactions at germanium(II) sites is discussed.

Phenyllithium reacts with cesium trichlorogermanate(II), $CsGeCl_3$, producing after hydrolysis, tetraphenylgermane, biphenyl, and a grey-black insoluble material.

1) $CsGeCl_3$ + excess PhLi $\longrightarrow$ Ph_4Ge + Ph-Ph + solid

Organolithium and Grignard Reagents react readily with chlorogermanes, substituting "R" groups for chlorine.

2) $4RLi + GeCl_4 \longrightarrow GeR_4 + 4LiCl$

Reaction 1) is somewhat unusual in that it formally pits two negatively charged reactants, Ph^- and $GeCl_3^-$, against one another. Ph_3Ge^- was an expected, though not realized product.

Relatively little has been accomplished in this area of divalent germanium chemistry. Few reactions "at" germanium(II) sites have been studied in depth, and germanium(II) iodide, GeI_2, has been the popular starting material. Glockling and Hooton (1963) have shown that excess phenyllithium reacts with GeI_2 at low temperatures to form tetraphenylgermane, triphenylgermane, and a high molecular weight polymer. Likewise, tert-butyllithium produces large quantities of rubbery, intractable, polymeric materials with GeI_2 under most conditions (Poskozim, 1967). Other reactions with GeI_2 have involved the use of Me_3Al (Glockling, 1967), i-Bu_3Al (Glockling, 1970), Ar_2Hg (Emelyanova, 1962), and n-Bu_2Hg and n-Bu_2Zn (Jacobs, 1954). Coupled germanium dimers, trimers, oligomers, and polymers are the predominant products. Scibelli and Curtis (1973) recently reacted sodium cyclopentadienide with germanium(II) bromide. Monomeric bis(cyclopentadienyl)germanium(II) forms first, then readily polymerizes.

Little of substance is known about the mechanism of these reactions. Some products parallel those obtained in Reaction 1) (vide supra), and we

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strongly suspect that the grey-black solid which we have isolated is also polymeric in nature.

EXPERIMENTAL

$CsGeCl_3$ was prepared from $GeCl_4$ and hypophosphorous acid (H_3PO_2) according to published procedures (Poskozim, 1967). Phenyllithium (1.86M in 70:30 benzene:ether) was purchased from Alfa Inorganics.

In a typical experiment (see Table 1), a measured volume of phenyllithium solution was added directly to 10.0g (0.032 moles) of solid, insoluble $CsGeCl_3$ powder. All reactions were performed under an atmosphere of dry air. After sufficient reflux time, the solution was cooled and hydrolyzed. The dirty-grey insoluble powder was filtered off. The organic phase was separated from the aqueous layer, the volatile solvents distilled off, and a white solid was collected. Addition of methanol dissolved the biphenyl product, affording its facile separation from the rather insoluble (in methanol) tetraphenylgermane. Subsequent removal of solvent methanol yielded white crystals of biphenyl.

Both tetraphenylgermane and biphenyl were recrystallized from toluene and acetic acid, respectively, and characterized by means of infrared spectra, melting point data, and carbon, hydrogen elemental analyses. Expected for Ph_4Ge ($C_{24}H_{20}Ge$): C, 75.65; H, 5.29%. Found: C, 75.53; H, 5.52% Melting point: 236°; found 232-234°. Expected for biphenyl ($C_{12}H_{10}$): C, 93.46; H, 6.54%. Found: C, 93.56; H, 6.56%. Melting point: 69-71°; found 49-55°.

The dirty-grey solid was quite insoluble in both organic and inorganic solvents, and did not melt to 300°C. Its infrared spectrum showed the characteristically strong Ge-Ph bands at 1069 cm^{-1} and 1410 cm^{-1}; bands at 844 and 750 cm^{-1} indicate the Ge-O stretching vibration (Poskozim, 1967). Carbon and hydrogen elemental analyses are quite inconsistent, providing no direct information as to the nature of the solid.

RESULTS AND DISCUSSION

Table 1 summarizes experimental conditions and results as obtained herein. Yields of products Ph_4Ge, Ph-Ph, and solid fluctuate mildly over Reactions I-IV; they drop off significantly in Reaction V when reactants are used in 1:1 molar ratios. The reaction of PhLi with $GeCl_4$ is included for the sake of comparison. While few specific patterns emerge from the data, what is interesting and unexpected are the relatively high yields of Ph_4Ge and Ph-Ph, and the absence of triphenylgermane, Ph_3GeH. This latter compound would come about upon hydrolysis of an expected triphenylgermyl anion, Ph_3Ge^- (Reaction 3). It is more difficult to write succinct, direct reactions to explain the

3) $GeCl_3^- + 3Ph^- \longrightarrow Ph_3Ge^- \xrightarrow{\text{hydrolysis}} Ph_3GeH$

presence of tetraphenylgermane and biphenyl.

TABLE 1: Distribution of products in the reactions of $CsGeCl_3$ and phenyllithium

Rx.	Molar Ratio PhLi: $CsGeCl_3$	Reflux Time (hours)	PRODUCTS								Molar Ratio GePh4: Ph-Ph
			$GePh_4$			Ph-Ph			"Polymer"		
			Grams	Moles	% Yield	Grams	Moles	% Yield	Grams		
I	6:1	1*	2.76	.0072	23	0.92	.0060	19	2.35		1.2
II	6:1	1	4.21	.0110	34	1.17	.0076	24	1.39		1.4
III	6:1	6	3.29	.0086	27	0.69	.0045	14	2.97		1.19
IV	4:1	1	2.39	.0063	20	0.37	.0024	7.5	1.82		2.6
V	1:1	1	0.36	.0009	3	0.16	.0010	3	0.38		0.9
VI	6:1**	1	8.43	.0221	69	--	--	--	--		

*Room temperature, no reflux.

**Molar ratio of PhLi to $GeCl_4$.

Reactions I-V based on 10.0 grams (0.032 moles) of $CsGeCl_3$.

Reaction VI based on 6.9 grams (0.032 moles) of $GeCl_4$.

There may well be several different mechanisms in operation here. Table 2 shows two possible pathways leading to the observed products. The "reductive coupling" sequence parallels Seyferth's (1957) work with Grignard reagents and $GeCl_4$. If one accepts this scheme, then it becomes difficult to understand why Ph_2Ge does not react further with PhLi to form $LiGePh_3$, and eventually Ph_3GeH upon hydrolysis. The presence of $GeCl_2$ in the "reductive coupling" scheme presents obvious similarities to the work done by Glockling and Hooton (1963) with GeI_2 (see Reaction 4 below).

$$4)\ GeI_2 + PhLi \xrightarrow[2.\ \text{Hydrolysis}]{1.\ \text{Low Temperatures}} \overset{7\%}{Ph_4Ge} + \overset{8\%}{Ph_3GeH} + \text{polymer} + \overset{0\%}{\square}$$

$$5)\ CsGeCl_3 + 4PhLi \xrightarrow[2.\ \text{Hydrolysis}]{1.\ \text{Reflux}} \overset{20\%}{Ph_4Ge} + \overset{0\%}{\square} + \text{polymer} + \overset{8\%}{\text{Ph-Ph}}$$

Reaction 5) was performed in this laboratory (Table 1). Note again the presence of Ph_3GeH in Reaction 4) and its absence in Reaction 5).

Disproportionation of $CsGeCl_3$ (Reaction 6) has been observed in sealed tubes at 140°C. Again, if one accepts this scheme, then the presence of

$$6)\ 2CsGeCl_3 \longrightarrow GeCl_4 + Ge + 2CsCl$$

germanium metal might well contribute to the dirty grey appearance of our solid "polymer" product. And the $GeCl_4$ could lead to the observed Ph_4Ge (See Reaction 2).

Efforts are now underway to obtain kinetic data on the reactions of $CsGeCl_3$ with PhLi. The two possible mechanistic schemes described above are reasonable models, and by no means meant to exclude other explanations of the facts. We are also trying to better characterize (see Experimental) the "polymeric" solid which is common to the $CsGeCl_3$/PhLi reaction.

ACKNOWLEDGEMENT

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TABLE 2: Possible mechanistic schemes in the reaction of $GeCl_3^-$ with Ph^-

Reductive Coupling	Disproportionation
$CsGeCl_3 + 2PhLi \longrightarrow Ph\text{-}Ph + GeCl_2 + CsCl + Li$	$2CsGeCl_3 \longrightarrow 2CsCl + Ge + GeCl_4$
$GeCl_2 + 2PhLi \longrightarrow Ph_2Ge + 2LiCl$	$GeCl_4 + 4PhLi \longrightarrow Ph_4Ge + 4LiCl$
$Ph_2Ge + H_2O \xrightarrow[\text{polymerization}]{\text{hydrolysis and}}$ solid (polymer)	

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PETROLEUM ETHER SOLUBLE CONSTITUENTS OF TRICHOLEPIS GLABERRIMA AND XANTHIUM STRUMARIUM FRUITS

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Abstract.--The petroleum ether extract of Tricholepis glaberrima was found to be mainly composed of C_{27}-C_{33} n-alkanes and C_{28}-C_{32} n-alkanols. The unsaponifiable portion of the Xanthium strumarium petroleum ether solubles consisted of C_{23}-C_{35} n-alkanes, C_{22}-C_{30} n-alkanols, and a sterol mixture of sitosterol, stigmasterol, and campesterol.

During a program directed toward a study of the medicinal plants in the Chandigarh, India area, we had occasion to examine the constituents of Tricholepis glaberrima DC and Xanthium strumarium Linn. Both plants have been employed in the indigenous medicine of the area for a variety of ailments (Chopra et al., 1956, p. 247; Kirtikar and Basu, 1933, p. 1356) so it seemed of interest to do a complete examination of their chemical components. Thus far, we have reported (Chawla et al., 1976) the presence of betulin, spinasterol, stigmasterol, and stigma-7-en-3-ol in T. glaberrima. Bhakuni and coworkers (1961) had analyzed the fruit oil of X. strumarium for its fatty acid composition and also indicated the presence of sitosterol and ceryl alcohol, while Tsukamoto and coworkers (1963) and Nishioku et al. (1965) indicated the presence of stigmasterol, sitosterol, and campesterol in the fruit. Work by Khafagy et al. (1974) with X. strumarium uncovered a phytosterol, $C_{28}H_{48}O_2$, and two triterpene alcohols, $C_{30}H_{50}O_2$ and $C_{30}H_{50}O_5$. More recently, we have presented results (Kapoor et al., 1976) about the fatty acid content of the fruit and seed oils of this plant. In this paper we wish to communicate the nature of the non-nitrogenous constituents of the fruits of both T. glaberrima and X. strumarium.

METHODS AND RESULTS

General.--The plant materials used in this study were collected near Chandigarh, India, and authenicated by Dr. J. K. Bhatnagar, Panjab University. Except as noted, gas liquid chromatographs (GLC) were performed on a Varian-Aerograph Series 2700 instrument with a flame ionization detector and an Autolab System IV computing integrator. A 5 ft. by 1/8 inch column of 1.5% OV-101 on 100/120 HP Chrom G was employed at

the temperatures indicated. Infrared spectra were recorded with a Perkin-Elmer 137 spectrophotometer on solids incorporated in KBr discs. The petroleum ether used for extractions and chromatography had bp 60-80°.

Tricholepis glaberrima.--Dried powdered fruits (800 g) were extracted in a Soxhlet apparatus to yield 18 g of crude plant material, which was chromatographed on alumina (400 g, S. Merck, India). The first fractions (3 x 150 ml) eluted with pet. ether gave a waxy substance (0.6 g) which could be crystallized from acetone to mp 68-70°; ν_{max} 728 and 717 cm^{-1} $[-(CH_2)_x-]$. GLC of the substance from 90-240° at 4°/min. exhibited signals corresponding to the following n-alkanes (% in mixture): C_{21}-C_{26} (traces), C_{27}(1.9%), C_{28}(1.5), C_{29}(23.1), C_{30}(5.2), C_{31}(60.3), C_{32}(2.8), C_{33}(5.2), C_{34}-C_{35}(traces). The next two fractions collected (150 ml each) afforded 0.2 g of residue with mp 65-68° which also proved to be an n-alkane mixture. It consisted of C_{23}-C_{26}(traces), C_{27}(3.3%), C_{28}(1.4), C_{29}(26.9), C_{30}(5.0), C_{31}(56.8), C_{32}(1.6), C_{33}(4.2), C_{34}-C_{35}(traces).

Further elution of the column with pet. ether-benzene (4:1; 4 x 150 ml) gave 0.4 g, mp 88-90° (from acetone); ν_{max} 3226 (O-H), 1059(C-O), 727, and 717 cm^{-1} $[-(CH_2)_x-]$. GLC of the material at 235° revealed it to be the n-alkanols: C_{26}(trace), C_{28}(11.1%), C_{29}(4.7), C_{30}(50.3), C_{31}(3.5), and C_{32}(26.3).

Xanthium strumarium.--The powdered fruits (1 kg) were extracted with pet. ether which gave an oil (131 g). The unsaponifiable matter (2.4 g) separated from the oil was chromatographed on alumina (120 g). Elution of the column with pet. ether (3 x 100 ml) produced a n-alkane wax (0.2 g) which crystallized from ethyl acetate with mp 62-65°; ν_{max} 728 and 717 cm^{-1}. GLC resolution of the material from 90-240° at 4°/min indicated an n-alkane composition of C_{23}(trace), C_{24}(1.2%), C_{25}(4.8), C_{26}(6.6), C_{27}(19.2), C_{28}(10.0), C_{29}(27.7), C_{30}(6.4), C_{31}(12,3), C_{32}(4.1), C_{33}(4.7), C_{34}(1.6), and C_{35}(1.4).

Fractions obtained with pet. ether-benzene (1:3; 3 x 100 ml) afforded 0.17 g of n-alkanols; mp 77-80° (from MeOH); ν_{max} 3279(O-H), 1055(C-O), 728 and 718 cm^{-1} $[-(CH_2)_x-]$. GLC analysis at 235° indicated the following straight chain alkanols: C_{22}(6.2%), C_{23}(1.8), C_{24}(29.4), C_{25}(3.6), C_{26}(18.8), C_{27}(trace), C_{28}(14.5), C_{29}(7.9), and C_{30}(13.4).

Subsequent elution of the column with benzene (7 x 100 ml) resulted in 0.4 g of sterols which were recrystallized from MeOH to mp 133-135°; ν_{max} 3268(O-H), 1053(C-O), and 962 cm^{-1} (trans C=C). GLC of the silyl derivative on a 6 ft by 1/8 inch column of 3% SE-30 on Chrom Q at 240° exhibited signals corresponding to sitosterol (65%), stigmasterol (28%), and campesterol (17%).

DISCUSSION

This report represents the first study and characterization of the petroleum ether solubles obtained from the fruits of Tricholepis glaberrima DC and Xanthium strumarium Linn. Although none of the compounds identified are unknown or unusual, several observations can be made from the % content of the various homologs in the n-alkane and n-alkanol fractions. For example, it can be noted that both the n-alkanes and n-alkanols from T. glaberrima are definitely concentrated in two compounds-nonacosane and hentriacotane

in the alkane series and triacontanol and dotriacontanol for the alkanols-because their percentages are considerably higher than the others. If the biosynthetic pathway whereby a fatty acid can give rise to an alkanol with the same number of carbons or an alkane with one less carbon (by decarboxylation) is assumed, it is clear that T. glaberrima fruits produce and use mainly the C_{30} and C_{32} fatty acids for the formation of its alkanes and alkanols.

Results from Xanthium strumarium fruits are not as clear. The percent composition of both the alkanes and alkanols are more diverse with the four largest components not differing markedly from each other and these as a group differing less than 10% from the next highest percentage group. Also, there is no correlation between one or two particular fatty acids and definite high content alkanes or alkanols. For example, 29.4% of tetracasanol is present in the alkanol mixture while no tricosane (C_{23}) which would result from the same fatty acid is found. Similarly, 12.3% of the C_{32} n-alkane occurs while the C_{32} n-alkanol is absent.

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FIRST RECORD OF THE LEAST BROOK LAMPREY, OKKELBERGIA AEPYPTERA, (PISCES: PETROMYZONIDAE) FROM ILLINOIS

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Abstract

The first record of the least brook lamprey, Okkelbergia aepyptera, from Illinois is presented. Meristic and morphometric characters are given. The least brook lamprey should be added to the State's rare and endangered species list.

The range of the least brook lamprey, Okkelbergia aepyptera (Abbott), is from southeastern Missouri to western Pennsylvania south to Arkansas and Georgia, and on the Atlantic slope from Maryland to North Carolina (Raney, 1941, 1952; Pflieger, 1971; Buchanan, 1973; Rohde et al., 1974). Data on the first record of this species from Illinois are presented. Use of the generic name Okkelbergia, rather than the traditional Lampetra, follows recommendations of Hubbs and Potter (1971). Five other lampreys have been recorded from Illinois (Smith, 1965).

A gravid female was collected in Big Creek, 4.8 km S of Karber's Ridge, Hardin County on 19 March 1971 (INHS 1091). This stream is a direct tributary of the Ohio River. In the vicinity of Illinois, O. aepyptera has been reported from Lick Creek, Orange County, Indiana, some 113 km northeast of the Illinois locality (Creaser, 1939); from Whippoorwill Creek, Logan County, Kentucky, some 147 km to the southeast (Clay, 1975); and from a tributary of Big Creek, Iron County, Missouri, some 204 km to the west (Pflieger, 1971). The discovery of the Illinois locality nicely fills the gap that existed between the previously known localities.

Meristic and morphometric characters (expressed as thousandths of total length) were as follows: myomeres, 60; total length, 147 mm, tail length, 265; trunk length, 551; branchial length, 99; prebranchial length, 97; snout length, 59; disc length, 37; body depth, 81; second dorsal fin height, 52; eye diameter, 19. These values compare favorably with those given by Rohde et al. (1976). Some pigment was present along the notochord in the caudal fin and extended slightly onto the fin.

An additional specimen, apparently referrable to O. aepyptera, was taken in Big Grand Pierre Creek, 3.2 km SE of Herod, Pope County, Illinois

on 22 August 1973 (INHS 1697). This stream is also tributary to the Ohio River. The specimen is an ammocoete (26 mm TL) and, except for slightly more pigmentation on the upper lip, fits the characters given by Vladykov (1950) for ammocoetes of O. aepyptera.

Despite extensive collecting by personnel of the Illinois Natural History Survey and others throughout the state, the lack of specimens indicates that O. aepyptera is apparently scarce in Illinois and should be placed on the State's rare and endangered species list. Additional collecting in the region may locate more populations.

I wish to thank Dr. Philip W. Smith, Illinois Natural History Survey, for the loan of the specimens and for graciously allowing me to report on them.

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POROID FUNGI DETRIMENTAL TO PINE IN SOUTHWESTERN ILLINOIS

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ABSTRACT. Phaeolus schweinitzii, Phellinus pini, Fomes annosus, and Fomes pinicola, all species of polypores (Aphyllophorales) which are known to attack standing pine, were collected in southwestern Illinois. This report represents the first Illinois record of F. pinicola, and the first known report of P. schweinitzii in southern Illinois. Distributional data and descriptions of the southwestern Illinois material and a discussion of their impact on introduced pine are included.

INTRODUCTION

Although pines are common trees in farm forest plantations and have been an introduced part of the southern Illinois flora for almost fifty years, there is very little documentation of their associated fungal flora. Because pines are economically important as pulpwood and Christmas-tree crops and since their ability to tolerate harsh sites makes them useful in stabilization of eroded abandoned fields and strip mine spoils, knowledge of their fungal associates would seemingly contribute to proper management practices. Therefore, I initiated a study of pine-associated Homobasidiomycetes (West, 1975). This report considers those polypores (Aphyllophorales) found in southwestern Illinois which are pathogenic to standing pine.

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MATERIALS AND METHODS

Description of study area

Pinus echinata Mill. (shortleaf pine) is native as only two relict populations in southwestern Illinois. It and three other species, *P. taeda* L. (loblolly pine), *P. strobus* L. (eastern white pine), and *P. sylvestris* L. (Scotch pine) were introduced to other areas formerly inhabited by native hardwoods. Although other pine species are sometimes encountered in southern Illinois plantations, only these four were considered in this study.

Within a five-county area of southwestern Illinois (Fig. 1), four plantations each of *P. echinata* and *P. taeda* were chosen as major collecting sites. Eight plantations of *P. echinata*, three of *P. taeda*, three of *P. sylvestris*, and one of *P. strobus* were utilized as minor sites. The major sites were visited at least once a month and the minor sites were visited irregularly. The native stand of *P. echinata* at Pine Hills (Union Co.) was frequently visited but only three collecting trips were made to the one at Piney Creek (Randolph Co.). All but a few collections were made within the five counties and during 1973.

Examination of specimens

Morphological data were taken from fresh specimens. Colors were described by comparison with standard color plates. Most color names and code numbers included here are those of Kornerup and Wanscher (1967; e.g., "milk white" [1A2]). Some color data were obtained by comparison with Ridgway's plates (Ridgway, 1912; e.g., Milk White). When it was not possible to match colors with a standard or where standard nomenclature seemed unclear, a common (author generated) name was employed and, if used, the standard nomenclature follows (e.g., white ["milk white", 1A2]).

Anatomical data were compiled largely from freehand sections of dried specimens mounted in 2.5% KOH. Contrast of hyaline structures was enhanced by adding 1% aqueous phloxine, and Iodine reactions were determined from mounts in Melzer's reagent.

Unless noted otherwise, dried collections were annotated and deposited in the Southern Illinois University Herbarium [SIU], Carbondale. Other collections were examined at the herbaria of the University of Illinois [ILL], Champaign-Urbana, the Field Museum of Natural History [F], Chicago, and Brandon University, Brandon, Manitoba, Canada.

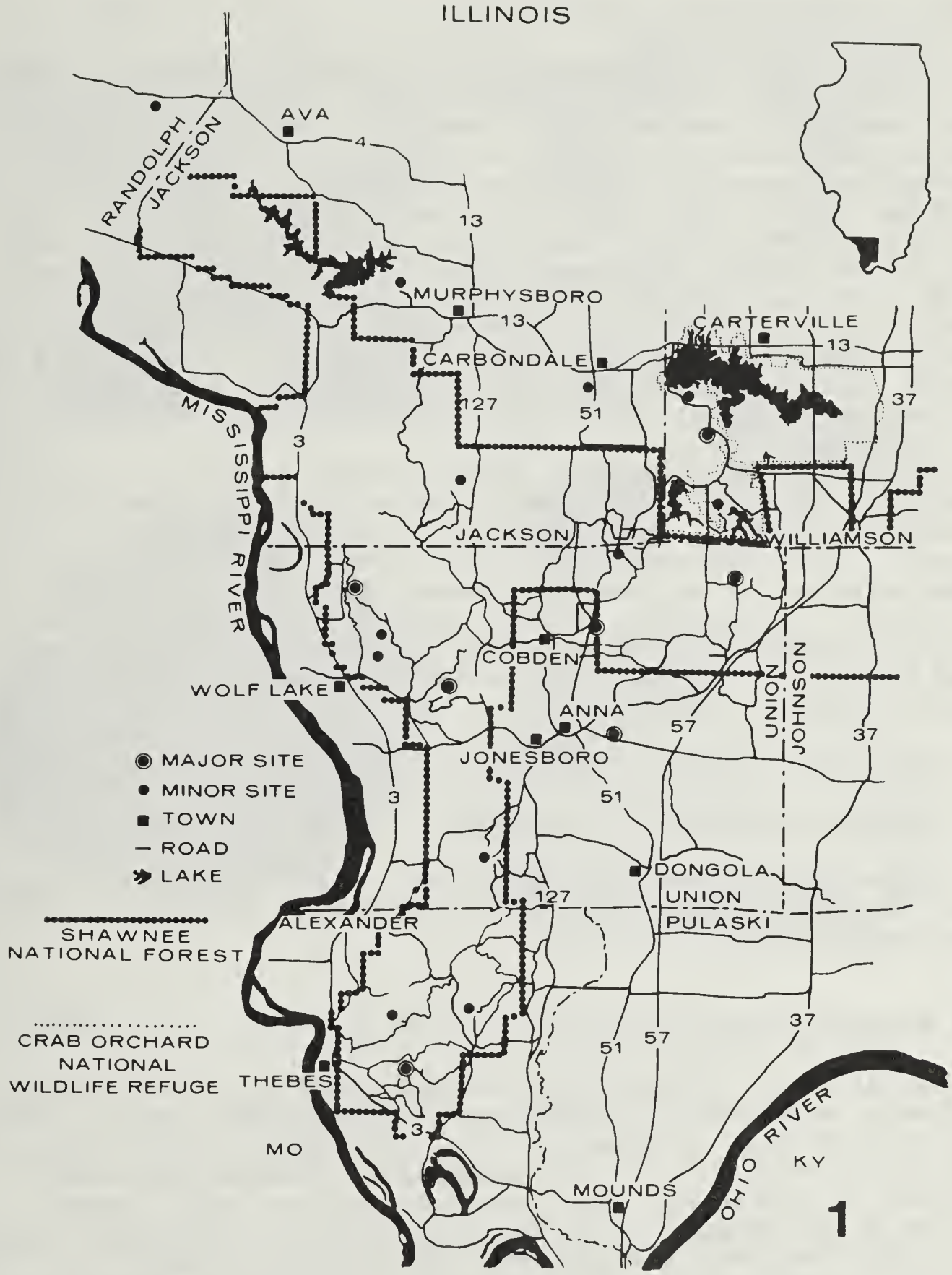


Fig. 1. Study Area.

RESULTS

Four species of pore fungi which are known to attack living pine were found during the survey.

Phaeolus schweinitzii (Fries) Pat. Figs. 2-3

Basidiocarps stipitate or substipitate, soft and fleshy when fresh, rigid and brittle when dry. Pileus 6.2 cm broad, depressed; surface dry, tomentose, azonate, rusty brown at the disc; margin entire, up to 5 mm thick, yellow-brown, scantily tomentose to glabrous. Context up to 1.2 cm thick, solid, yellow, soon turning brown when cut, turning red then quickly black where touched with KOH. Tube layer 1-6 mm thick, decurrent, concolorous with the context. Pore surface mustard yellow, darker where bruised and upon drying. Pores 1-3 per mm, walls angular, breaking up, becoming irregular and subdentate. Stipe 4.5 cm long, 1.4 cm broad at apex, tapering downward; surface dry, tomentose, light yellow-brown at apex, rusty brown at base.

Basidiospores (5-)6-7 x (2.5-)3-4 µm, ovate to elliptical; surface smooth; walls thin; hyaline, inamyloid and not dextrinoid. Basidia 14-18 x 5-6 µm, clavate, 4-spored. Cystidia scattered, 26-72 x 4-6 µm, cylindrical to slender-clavate, sometimes mucronate; walls thin, smooth; light brown; originating in the trama and protruding up to 60 µm beyond the adjacent basidia. Tramal hyphae monomitic, 2-6 µm broad, septa uncommon; walls thin, smooth; brown. Clamp connections absent.

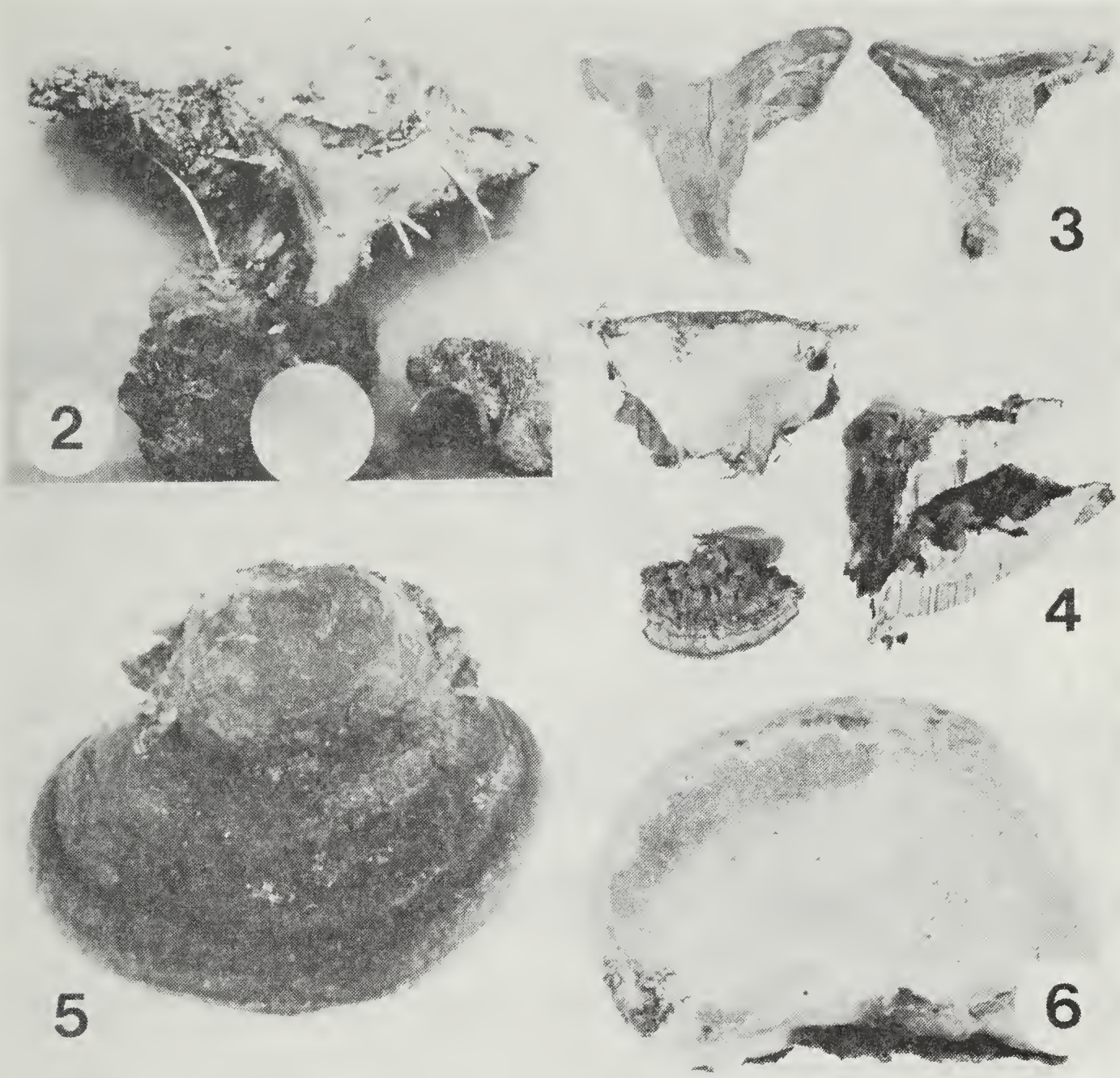
Habit and habitat: Solitary on well decayed Pinus log.

Specimen examined: Williamson Co.: Halbrendt 2.

Extralimital specimens examined: ILLINOIS. Ogle Co.: RWS 61 (Ex herb. R. W. Schanzle). INDIANA. Lake Co.: Harper s.n. [F].

Fomes annosus (Fries) Karst. Fig. 4

Basidiocarps effused-reflexed to sessile, occasionally resupinate, solitary to imbricate, leathery when fresh, rigid and hard when dry. Pileus 3.2-11.2 cm broad, 0.4-5.5 cm thick, protruding 1.7-5.4 cm, applanate; surface sparsely tomentose to glabrous, often encrusted with a hard, brown pellicle which appears as a black layer up to 1 mm thick over the lighter context, azonate and "greyish red" (7B5) to "brownish orange" (7C5) or zonate with alternating bands of "grey" (4B1), "greyish red" (7B3), and "brown" (7E6); margin entire, up to 2 mm broad, brown ("red haired", 6C4 to "Sahara", 6C5), glabrous to sparingly tomentose. Context 0.2-1 cm thick, "milk white" (1A2) to "yellowish white" (4A2), leathery when fresh, rigid upon drying. Tube layer not distinctly stratified, 3-9 mm thick, the separate layers 1-7 mm long, "cream" (4A3) to "orange white" (6A2). Pore surface "milk white" (1A2) to "greyish orange" (5B4) to brown ("red haired", 6C4). Pores 2-4(-5) per mm, usually round to



Figs. 2-3. Phaeolus schweinitzii. 2. Harper s.n., X 2/5. 3. Halbrendt 2, X 2/5.

Fig. 4. Fomes annosus. West 1085, X 1/4.

Figs. 5-6. Fomes pinicola. BU 110, X 1/5.

angular, sometimes varying to daedaleoid; walls moderately thick, entire.

Basidiospores 3-5 x 3-4 µm, globose to subglobose; surface smooth; walls thin; hyaline, inamyloid and not dextrinoid; usually uniguttulate. Basidia 12.5-24 x 4-5 µm, clavate to cylindrical, most 4-spored, but occasionally 2-spored. Tramal hyphae dimitic. Generative hyphae 2.5-3.5 µm broad; sparingly branched, scattered and uncommon in the context, more commonly found in the tube trama near

the hymenium; hyaline. Skeletal hyphae 2-4 µm broad; occasionally contorted, compactly interwoven and abundant in the context, more or less parallel in the tube trama; hyaline. Clamp connections absent.

Habit and habitat: Solitary to imbricate, sometimes resupinate on decayed stumps and roots of wind-thrown living or dead trees, on roots of standing living and dead trees beneath ground level in the humus and occasionally on lower trunk surfaces of standing trees up to three feet above the ground. On native and introduced Pinus echinata, P. strobus, P. taeda, various undetermined Pinus spp. and one collection on apple tree roots.

Specimens examined: Alexander Co.: West 892. Jackson Co.: Hinkle and West 90; West 295, 1045. Union Co.: West 1038, 1041, 1088. Williamson Co.: West 199, 200, 826, 1085.

Extralimital specimens examined: Hardin Co.: West 1051. Johnson Co.: West 033.

Fomes annosus was previously reported from Illinois by Moffatt (1909), Graham (1944) and Schanzle (1971), and its extent on the Crab Orchard National Wildlife Refuge in Williamson County has been documented (Jordon, 1969).

More recently, workers have applied the name Heterobasidion annosum (Fries) Brefeld to this species.

Fomes pinicola (Swartz ex Fries) Cooke Figs. 5-6

Basidiocarp sessile, hard and rigid. Pileus 2.6 cm broad, 2.3 cm thick, protruding 1.9 cm, subcircular, ungulate; surface glabrous, hard and appearing resinous, azonate, "brownish orange" (6C6) to "reddish golden" (6C7); margin distinctive, obtuse, entire, soft-corky and easily indented when fresh, drying rigid, "milk white" (1A2) to "pale yellow" (1A3), turning red upon application of KOH, glabrous. Context up to 1 cm thick, cream to "light orange" (5A4-5), changing to red when touched with KOH, corky when fresh, drying rigid. Tube layer distinctly stratified, up to 3 mm thick, more or less concolorous with context. Pore surface "milk white" (1A2), turning red in KOH. Pores 3-5 per mm, round to angular; walls rather thick and entire.

Basidiospores 5-6 x 2-3 µm, ovoid to elliptical; surface smooth; walls thick; hyaline, inamyloid and not dextrinoid. Basidia 11-13 x 5-8 µm, clavate, 4-spored. Cystidia scattered, 23-28 x 2-3 µm, clavate to cylindrical, originating within the trama, protruding up to about 15 µm beyond the adjacent basidia; walls smooth; clamp connections often at basal septum. Tramal hyphae dimitic. Generative hyphae

1.5-3 µm broad, scattered throughout the context; clamp connections present. Skeletal hyphae 4-6 µm broad, interwoven in the context and tube trama; clamp connections absent.

Habit and habitat: Solitary on the lower trunk surface of living native P. echinata.

Specimen examined: Union Co.: West 224.

Extralimital specimens examined: CANADA. Manitoba: BU 110, West 601 (Ex herb. Brandon University). TENNESSEE. Sevier Co.: West 1064.

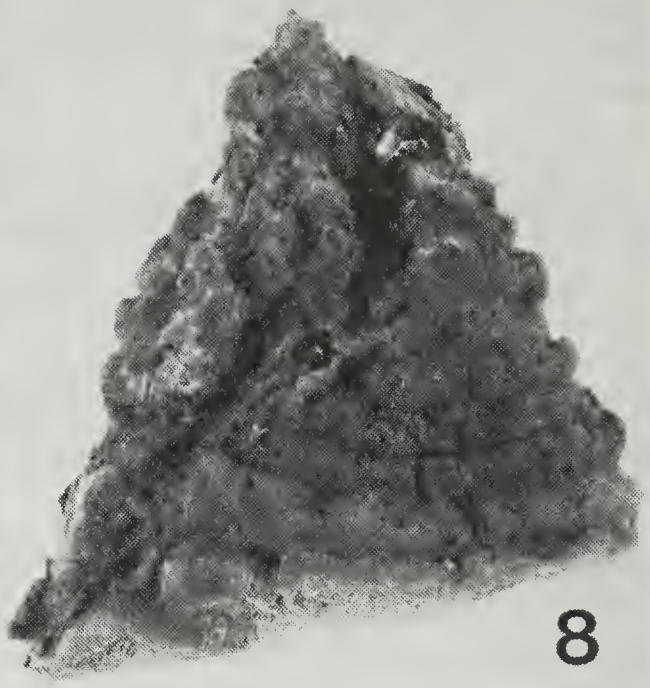
This collection, which represents the first account of F. pinicola in Illinois, is a small diminuative basidiocarp. The extralimital specimens examined also produced small basidiocarps similar to the Illinois material as well as larger, applanate to subungulate fruiting bodies (up to 20 cm broad, 5.4 cm thick and protruding up to 12.5 cm; Figs. 5-6). Additionally, they all exhibited similar anatomical details and the same distinctive KOH-red macrochemical reaction. These extralimital specimens were collected from the lower to mid-trunk area of various coniferous hosts including Pinus banksiana Lamb., Picea sp. and Tsuga canadensis (L.) Carr.

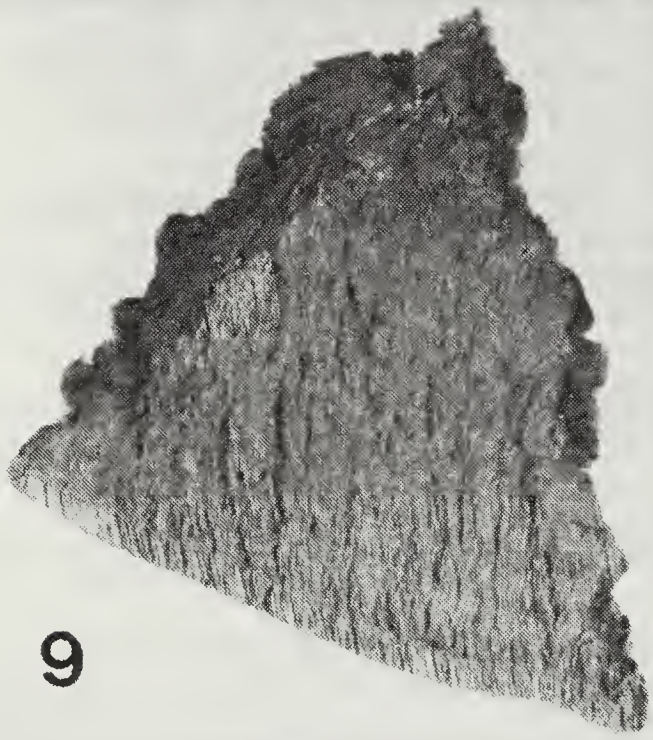
The binomial Fomitopsis pinicola (Sw. ex Fries) Karst. is often used for this species.

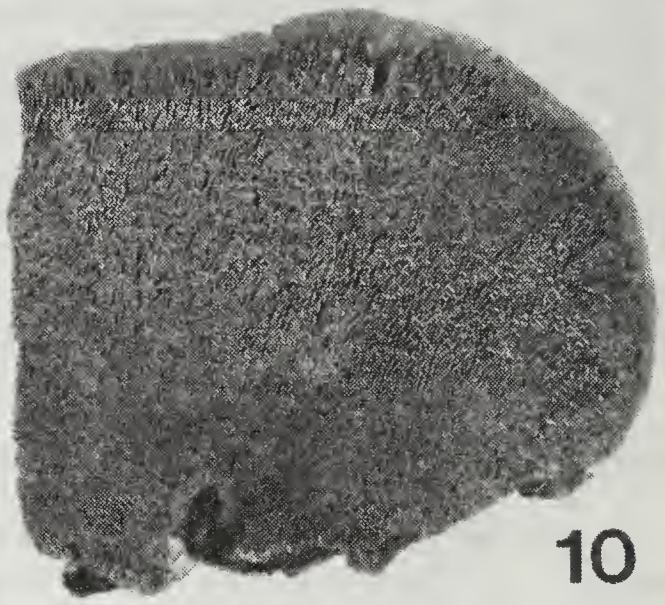
Phellinus pini (Thore ex Fries) Pilát Figs. 7-10

Basidiocarps sessile to effused-reflexed, hard and woody. Pileus 4.3-14.1 cm broad, 2.4-7.4 cm thick, protruding 2.9-9.2 cm, usually ungulate but occasionally applanate; surface tomentose to glabrous, becoming encrusted and cracked-rimose with age; "brown" (6E5) to reddish brown ("Titan red", 7D6 to "greyish brown", 7F5), all parts black where touched with KOH; margin prominent, rounded or furrowed, often zonate and appressed-fibrillose, entire, 2-5 mm wide, "brown" (6E5-6) to reddish brown ("brick red", 7D7). Context 0.5-6.8 cm thick, golden yellow ("Indian yellow", 5B7) to "brownish orange" (6C6-8) to "greyish red" (7B5-6). Tube layer 3-5 mm thick, distinctly stratified, often sunken unequally into context, separate layers 1-3 mm broad, "reddish white" (7A2) to "greyish red" (7B6). Pore surface "greyish orange" (6B3-6) to "brownish orange" (6C6-7C5). Pores from less than 1 up to 3 per mm, round to daedaleoid; walls thick, entire.

Basidiospores (4-)5-6 x 4-6 µm, globose to subglobose; surface smooth; walls thin to moderately thick; hyaline to







Figs. 7-10. Phellinus pini. West 1040. 7. Habit on living Pinus echinata. 8. Upper surface, X 1/4. 9. Context and tube layers, X 1/4. 10. Pore surface X 1/4.

brown; inamyloid and not dextrinoid. Basidia 15-29 x 4-6 µm, clavate, sometimes medially constricted, 4-spored. Setae abundant, 37-71.5 x 5-13 µm, subulate to lanceolate; walls up to 4 µm thick, smooth; reddish brown. Tramal hyphae dimitic. Generative hyphae scattered, 2-3 µm broad, hyaline. Skeletal hyphae tightly interwoven in context, more or less parallel in the tube trama, 2-4 µm broad, brown. Clamp connections absent.

Habit and habitat: Solitary on living, standing native

P. echinata; mostly on trunks up to 10 feet above ground, but occasionally at the base or on exposed roots.

Specimens examined: Randolph Co.: West 1056. Union Co.: West 046, 836, 1040, 1043; J. K. Bouseman s.n. [ILL].

Phellinus pini was not evident in plantations. It has previously been recorded from Illinois only by Owens (1936) and Schanzle (1971).

This species is often cited as Fomes pini (Thore ex Pers.) Lloyd or Trametes pini (Thore) Fries in forestry literature.

DISCUSSION

The perennial basidiocarps of Fomes annosus and Phellinus pini can be found during all seasons. Basidiocarps collected in early spring through late fall were usually fertile while the majority of those collected in winter were not, suggesting a seasonal periodicity in sporulation. Anatomical details of the hymenia of winter collections were often obscured by Fungi Imperfecti, or the hymenia were collapsed or sterile. Although data are lacking for Fomes pinicola, it also produces perennial basidiocarps and probably follows a similar pattern to the preceding species in southern Illinois. Phaeolus schweinitzii produces annual basidiocarps which deteriorate relatively slowly. It fruits in late summer in Arkansas (Hepting and Chapman, 1938) and midsummer to late fall in the northeastern United States (Smith, 1970). Thus, its appearence in southern Illinois in July is not surprising, but more collections are needed to establish its fruiting period with certainty.

Phaeolus schweinitzii causes red-brown butt rot in living conifers (Harvey, 1962). In pine stands of the southeastern States, where it is responsible for much commercial cull, it gains entrance mainly through fire wounds; less commonly root infection also occurs (Hepting and Chapman, 1938). Although collected from only one area in Crab Orchard National Wildlife Refuge, many of the pine plantations there have trees with butt and root decay, and it is probable that P. schweinitzii, as well as F. annosus, may be responsible. In the Crab Orchard stands, prescribed burning is used to inhibit native hardwood reproduction under the plantations, and since fire apparently predisposes pine to infection by P. schweinitzii, this fungus will probably become a more prevalent pathogen in those stands where fire is used in management.

Phellinus pini is responsible for much commercial cull in Douglas fir in the northwestern United States, in eastern white pine in the northeast, and in the yellow pines of the southeast (Hepting, 1971). Its decay ("red heart" or "red rot") is most important in stands older than 80 years (Hepting and Chapman, 1938). Even though now present in only the two native pine stands, it will most likely spread to plantations managed using long term rotations, and will probably be particularly damaging to those managed in sawlog production. However, if mechanical damage (careless pruning, logging wounds, fire scars) is prevented, infection frequency may be reduced in older stands.

Fomes pinicola is common in most coniferous forests excepting those of the southern United States. It too causes trunk rot, but probably attacks only weakened individuals since it is much more prevalent in decays of fallen timber (Overholts, 1967). Its presence in southern Illinois is interesting because it was found on native P. echinata, a southern pine species, and the major part of its known range is the northern, Appalachian, and western coniferous forests, notably on Pseudotsuga, Abies, Picea and Tsuga. Even though only one collection is now documented, it is possible that it is more widely distributed in the native stands at Pine Hills but is not actively fruiting.

Fomes annosus was collected in almost all plantations examined, particularly in those which were cut over. It invades exposed stump surfaces, infecting root grafts of adjacent healthy trees. Its presence as a serious root pathogen will continually be a management problem. Treatment of freshly cut stumps during thinning operations should reduce the incidence of infection in the remaining trees of the stand.

CONCLUSIONS

Distribution and occurrence of Fomes annosus, F. pinicola, Phellinus pini, and Phaeolus schweinitzii in southwestern Illinois are apparently influenced by stand conditions. Although the two heart-rotting species, P. pini and F. pinicola, are currently known only from native pine stands, they will probably spread to older plantations. If a pine lumber market is projected for southern Illinois, these species will most likely adversely affect local plantations just as they affect those in the southern States. Ultimately, however, losses from root and trunk rots caused by the more aggressive species F. annosus and P. schweinitzii will perhaps be even more significant.

Because the presence of these pathogenic fungi will

ultimately influence forest management, future studies should be constructed to monitor the occurrence and spread of these species in southern Illinois.

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PALEOECOLOGICAL NOTES ON THE FAUNA OF THE SHUMWAY LIMESTONE (MATTOON FORMATION, UPPER PENNSYLVANIAN) OF ILLINOIS

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Abstract: The fauna of the Shumway limestone including 21 brachiopod species, 20 pelecypod species, 14 gastropod species, 1 scaphopod species, 16 cephalopod species, 2 cnidarians, a trilobite, crinoid columnals, unidentified bryozoans and fragments of vertebrates is listed. Vertical preservation of nautiloids suggest that water depth was less than 10 m while the presence of 21 genera of brachiopods would suggest a depth greater than 20 m. The use of brachiopod diversity which may be related to environmental complexity as well as depth is not wise unless some independent means of confirmation is used. The contained fauna of the unit suggests that the depositional environment was shallow, quiet water over a limey mud bottom that supported a growth of submerged plants.

INTRODUCTION

Community analysis of Paleozoic marine faunas has been approached from two conceptual frameworks. Johnson (1960, 1962, 1964) defined communities on the basis of mutually associated species. Johnson (1962) showed that 19 groups of mutually associated species exist based on analysis of 152 fossil collections (see Wanless, 1958) from the Middle Pennsylvanian of western Illinois. These groups could be further grouped into three basic associations which were significantly correlated with particular lithologies as follows: the Chonetina association (upper limestones-calcareous shales), the Gastropod association (calcareous shales-upper limestones) and the Orbiculoidea association (black fissile shales). Watkins (1974) and Gilliam and Schram (1975) describe and name other Pennsylvanian associations. Gilliam and Schram's (1975) Kozlowskia-Neospirifer community is an unnecessary name since it is identical in nearly all respects to Johnson's (1962) Group I, a part of the Chonetina association. Watkins' (1974) associations are less directly comparable to Johnson's since the methods of analysis differed, the time span studied differed and faunal differences exist between Pacific and Mid-Continent sites.

Another significant method of community analysis is based on trophic level analysis (Turpaeva, 1953). Several workers (Walker and Laporte, 1970; Rhoads et al., 1972; Walker, 1972; Walker and Bambach, 1974 among

others) have modified Turpaeva's (1953) methods and applied them to fossil marine benthic communities. Studies of this nature not only point out that associations of species exist but also attempt to interpret ecological interactions of individual members of the fauna and evolutionary dynamics of marine benthic communities.

This paper presents a faunal list from the Shumway limestone. Paleoecological inferences are based on this fauna. Evidence that the use of brachiopod diversity as an estimate of depth may not be completely reliable is presented.

MATERIAL AND METHODS

Samples of megafossils were collected for identification. Collections were made over a period of 12 years. Specimens are in the private collection of the author and in the Field Museum of Natural History, Chicago (mostly nautiloids). Identifications are based on literature and comparisons with specimens in the collections of Illinois State University and the Wanless collections at the Illinois Geological Survey. Comparisons to other faunas are based on the species level where possible and the generic level in some cases. In all cases generic level taxonomy follows that given in appropriate sections of the Treatise on Invertebrate Paleontology (R. C. Moore, ed.). The Shumway limestone is a very hard micritic limestone that makes quantitative sampling very difficult. Consequently relative abundances are subjectively measured based on 12 years of experience with the fauna. Abundant species (A) are those that are likely to be found in nearly any piece of limestone that has a surface area of 20 square inches. Common species (C) are those that may be collected on every visit to the unit. Rare species (R) are those that are seldom encountered. Species represented by only one specimen are recorded as unique (U). Although microfossils are present, they are not considered in this report.

Johnson (1962) pointed out that random sampling to determine relative abundances of taxa may not be adequate for paleoecological studies. Rare species which may be important ecological indicators may be overlooked. Sight collecting while possibly providing a more complete sample of the fauna does not give an objective measure of the relative abundance of various members of the fauna. Sight collections may also reflect the individual biases of the collector. Collections from the Shumway limestone that this report is based on are biased in that the collection of nautiloid cephalopods is a primary objective of the author's studies. But since the nautiloid fauna is not used for any ecological inferences except for water depth, the effect should be unimportant.

STRATIGRAPHY

The Shumway limestone which is part of the Shumway Cyclothem of the Mattoon formation is made up of a lower bed and upper bed. The contact between them is relatively distinct and they are lithologically distinctive as well. The lower bed is a fine grained almost lithographic micritic limestone that when fresh is very hard. The upper bed is much more argillaceous and is very slightly bedded. All collections reported here are from the lower bed of the Shumway limestone. Kosanke et al. (1960) described the stratigraphic section containing the Shumway Cyclo-

them at the type locality which is the collecting site for the species reported here. It is located 2 mi E of Shumway, Effingham Co., Ill. (SE ¼, SE ¼, SW ¼ sec. 26, T9N, R5E, Effingham Quadrangle). The marine portion of the cyclothem closely approaches the ideal cyclothem of Weller (1957). Bed 9 of the ideal cyclothem corresponds to the lower bed of the Shumway limestone. Correlations within the Mattoon formation are unsure (Kosanke et al., 1960) but the Shumway limestone is considered to be uppermost Missourian or lowermost Virgilian and roughly correlates with the Lawrence shale or the Iatan limestone of the Mid-Continent (Kosanke et al., 1960). Occurrence of the fusulinid genus Triticites (Weller et al., 1942) supports these correlations.

THE FAUNA

The megafossils collected from the Shumway limestone are listed in Table 1. Interpretations of the life habits of Shumway limestone pelecypods and gastropods follow Kauffman (1969) and Knight et al. (1960) where possible.

DISCUSSION

Certain aspects of the fauna strongly suggest that plants were an important part of the environment. The gastropod fauna contains Euphemites, Pharkidonotus and Glabrocingulum which were almost certainly herbivorous (Knight et al., 1960). The other Archeogastropoda and Mesogastropoda may also have been herbivorous. Smaller pedunculate brachiopods (Table 1) are much more common than the larger pedunculates (Table 1). The pelecypod fauna parallels this in that smaller byssate species (Table 1) are much more common than larger byssate species (Table 1). Pteronites sp. is an exception to this as it is moderately common. However, unlike other byssate species Pteronites was probably partially infaunal (Kauffman, 1969). The relative rarity of larger byssate pelecypods and larger pedunculate brachiopods as compared to smaller species of each group suggests that suitable substrates for attachment for the larger species was rare. Rhoads et al. (1972) and Kauffman (1969) suggested that smaller byssate pelecypods may use vegetation for attachment sites. Johnson (1962) suggested that a high incidence of gastropods in association with an infauna indicates the presence of plants on a soft substrate.

If the Shumway limestone was deposited at a site of moderately heavy although possibly patchy plant growth on a relatively soft substrate then certain features of the fauna are explicable. Plants may have been strong enough to support smaller pedunculate brachiopods and byssate pelecypods but too weak to support larger pelecypods and brachiopods. Pelecypods which utilize a relatively uncoordinated swimming reaction to escape predators could be hampered by vegetation and their rarity may thus be correlated with plant growth. While plants could conceivably interfere with swimming pelecypods which are relatively uncoordinated, there is no reason to believe that it would disturb nautiloid cephalopods which utilize strong coordinated swimming movements. Cephalopods would also have the water column above any plants or bare patches between plants available to them.

Johnson (1962) noted that lophophyllid corals and Crurithyris are

TABLE 1. Feeding category, life site, abundance (Ab) and group number (Johnson, 1962) of faunal elements of the Shumway limestone.

Identity	Feeding category	Life site	Ab	Group	Remarks
Brachiopoda					
Cancrinella boonensis (Swallow)	suspension	epifaunal	C	-	productid
Neochonetes granulifer (Owen)	suspension	epifaunal	A	I	productid
Linoproductus prattenianus Dunbar & Condra	suspension	epifaunal	C	VIII	productid
Reticulatia huecoensis (King)	suspension	epifaunal	C	I	productid
Echinaria sp.	suspension	epifaunal	C	I	productid
Retaria lasallensis (McChesney)	suspension	epifaunal	A	I	productid
Juresania symmetrica (McChesney)	suspension	epifaunal	R	IX	productid
Kozlowskia splendens (Norwood & Pratten)	suspension	epifaunal	A	I	productid
Lissochonetes geinitzianus (Waagen)	suspension	epifaunal	A	XIV	productid
Derbyia crassa (Meek & Hayden)	suspension	epifaunal	C	I	free lying
Derbyoides nebrascensis Dunbar & Condra	suspension	epifaunal	C	-	free lying
Punctospirifer kentuckyensis (Shumard)	suspension	epifaunal	C	I	free lying-pedunculate
Neospirifer triplicatus (Hall)	suspension	epifaunal	C	I	free lying-pedunculate
Composita subtilita (Hall)	suspension	epifaunal	R	I	large pedunculate
Enteletes hemiplicatus (Hall)	suspension	epifaunal	R	-	large pedunculate
Cleiothyridina atrypoides (Girty)	suspension	epifaunal	C	I	small pedunculate
Phricodothyris perplexa (McChesney)	suspension	epifaunal	R	VII	small pedunculate
Wellerella osagensis (Swallow)	suspension	epifaunal	C	IX	small pedunculate
Rhipidomella carbonaria (Swallow)	suspension	epifaunal	C	-	small pedunculate
Hustedia marmoni (Marcou)	suspension	epifaunal	C	II	small pedunculate
Pelecypoda					
Wilkingia costatum (Meek & Worthen)	deposit	infaunal	C	XIV	
Palaeoneilo taffiana (Girty)	deposit	infaunal	C	-	
Nuculopsis girtyi Schenck	deposit	infaunal	C	II	
Astartella compacta Girty	suspension	epifaunal	C	II	free lying?
Placunopsis carbonaria	suspension	epifaunal	R	-	byssate?
Monopteria longa (Geinitz)	suspension	epifaunal	R	-	byssate
Edmondia ovata Meek & Worthen	deposit	infaunal	R	-	

TABLE 1 continued.

Identity	Feeding category	Life site	Ab	Group	Remarks
Palaeolima retifer (Shumard)	suspension	epifaunal	C	III	small byssate
P. equistriata (Boebe)	suspension	epifaunal	C	III	small byssate
Fasciculiconcha knighti Newell	suspension	epifaunal	R	-	large swimmer or byssate
Rhestia bellistriatus (Stevens)	deposit	infaunal	R	XIII	
Parallelodon sangamonensis (Worthen)	suspension	epifaunal	R	XV	large byssate
P. obsoletus (Meek)	suspension	epifaunal	R	XV	large byssate
Schizodus sp.	suspension	epifaunal ?	R	-	byssate ?
Solemya trapezoides Meek	deposit	infaunal	R	III	
Volsellina subelliptica (Meek)	suspension	epifaunal	C	-	small byssate
Acanthopecten carboniferus (Stevens)	suspension	epifaunal	U	-	swimmer or byssate
Pteronites sp.	suspension	infaunal	C	-	byssate ?
Pernopecten ohioensis (Newell)	suspension	epifaunal	R	VIII	swimmer ?
Modiomorpha sp.	suspension	epifaunal	C	-	byssate
Gastropoda					
Euphemites carbonarius (Cox)	browser	epifaunal	R	II	
Glabrocingulum grayvillense (Worthen & Pratten)	browser	epifaunal	C	II	
Pharkidonotus percarinatus (Conrad)	browser	epifaunal	C	II	
Straparolus subquadratus Meek & Worthen	browser	epifaunal	C	XVI	
Trepospira depressa (Cox)	browser	epifaunal	R	VI	
Worthenia tabulata (Conrad)	browser	epifaunal	C	-	
Bellerophon stevensianus McChesney	browser	epifaunal	R	-	
Shansiella sp.	browser	epifaunal	R	-	
Lepetopsis sp.	suspension	epifaunal	U	-	
Ianthinopsis brevis (White)	? predator	epifaunal	R	II	
I. paludinaeformis (Hall)	? predator	epifaunal	C	II	
I. primogenius (Conrad)	? predator	epifaunal	C	II	
Meekospira sp.	? predator	epifaunal	R	VI	
Stephanozyga sp.	? predator	epifaunal	R	-	

TABLE 1 continued.

Identity	Feeding category	Life site	Ab	Group	Remarks
Scaphopoda					
Prodentalium sp.	suspension	infaunal	U	XII	
Cephalopoda					
Mooreoceras sp.	predator	nektobenthos	C	-	
Brachycycloceras dilatatum (Meek & Worthen)	predator	nektobenthos	R	-	
B. normale Miller, Dunbar & Condra	predator	nektobenthos	R	-	
Tainoceras monilifer Miller, Dunbar & Condra	predator	nektobenthos	C	-	vertically entombed
T. sexlineatum Tucker	predator	nektobenthos	R	-	
Cooperoceras sp.	predator	nektobenthos	U	-	
Metacoceras copei Tucker	predator	nektobenthos	C	IX	vertically entombed
M. mechesneyi Murphy	predator	nektobenthos	U	IX	
Domatoceras wortheni Tucker	predator	nektobenthos	C	-	vertically entombed
D. mattoonensis Tucker	predator	nektobenthos	R	-	vertically entombed
Stearoceras involutum Tucker	predator	nektobenthos	U	-	
Solenochilus shumwayense Tucker	predator	nektobenthos	C	-	vertically entombed
Liroceras liratum (Girty)	predator	nektobenthos	C	-	vertically entombed
Ephippioceras moinellae Tucker	predator	nektobenthos	R	-	vertically entombed
Goniloboceras sp.	? predator	nektobenthos	R	-	
Eoasinites sp.	? predator	nektobenthos	R	-	
Other fossils					
Echinodermata-crinoid columnals	suspension	epifaunal	R	I	
Cnidaria					
Lophophyllidium proliferum (McChesney)	predator	epifaunal	R	XII	
Paraconularia sp.	? predator	epifaunal	R	-	
Bryozoa					
encrusting form or forms	suspension	epifaunal	R	-	
upright ramose form or forms	suspension	epifaunal	R	-	
Arthropoda-Ameura sp.	deposit	epifaunal	R	-	
Annelida-Serpulopsis sp.	suspension	epifaunal	A	XVII	

Rare vertebrate teeth fragments (chondrichthine) and rare stems and logs of woody plants present as well.

negatively correlated. He suggested that this may reflect different substrate prferences. At Shumway, lophophyllids are rare while Crurithyris is a common fossil. It may be that lophophyllids are not successful in areas with abundant plant growth. Vegetation could cause sediments to settle out of suspension by slowing water movements. Heavier sedimentation may be detrimental to corals, bryozoans and crinoids whose feeding structures are exposed than for brachiopods whose lophophore is enclosed by the shell. The rarity of crinoids, bryozoans and corals may also be due to the soft substratum which is indicated by the common productid brachiopods and the number of infaunal pelecypods.

The high diversity of brachiopods (21 genera) should indicate a water depth of greater than 20 m (Stevens, 1971). However, specimens of seven species of coiled nautiloids have been found vertically entombed with the venter of the living chamber oriented toward the substrate. Vertical preservation of coiled cephalopods may be taken as evidence that water depth was less than 10 m (Raup, 1973; Weaver and Chamberlain, 1976) if the cephalopod is reasonably similar morphologically to Nautilus pompilius and if the vertical orientation cannot be attributed to secondary disturbance. E. moinellae and L. liratum are reasonably similar to N. pompilius in gross shape. Neither of these species have flat venters or spines that could act as stabilizing platforms even after the phragmocone filled. There is no evidence that any of the vertically preserved nautiloids were secondarily disturbed. While it is possible that a nautiloid sinking into plants could be kept from falling over by surrounding vegetation, two things suggest that this is unlikely. If plants were not able to support larger byssate pelecypods and pedunculate brachiopods, it seems unlikely that they would be able to support even larger nautiloids. More importantly Weaver and Chamberlain (1976) showed that beyond a depth of 7 m, rapidly filling Nautilus shells sink in a horizontal orientation. Slowly filling shells may sink vertically oriented for depths as great as 600 m but will fall over within one to two days after settling due to fillage. Consequently vertical preservation should be rare beyond a depth of 10 m (Weaver and Chamberlain, 1976).

The disagreement between depth inferences based on cephalopod preservation and brachiopod diversity could be an artifact if the fauna preseved in the Shumway limestone was carried there after death. This seems unlikely for several reasons. Many of the productid brachiopods have well preserved spines. Few of the fossils show any signs of wear and benthic organisms are commonly found complete and unbroken. Only rarely are disarticulated brachiopods found. It is also possible to correlate the life habits of the pelecypods with their mode of preservation. Infaunal pelecypods are found with the valves articulated and generally closed. Epifaunal pelecypods are usually found as disarticulated valves though in smaller byssate species the valves are often found articulated but opened or disarticulated and lying near each other. Pteronites which is shallowly infaunal are usually found disarticulated but with the valves lying near each other. Micritic limestones usually form in areas where current transport is limited (Laporte, 1968). Valentine (1961), Johnson (1965) and Warme (1969) have all shown that buried dead shells reflect the organisms living in the area even in some cases where strong currents exist (Warme, 1969). Apparently then, at least the benthic fauna lived at or near the site of collection. No indications of faunal or lithological changes are present within the lower bed of the Shumway limestone which averages less than one foot thick. Consequently it is difficult

to attribute high brachiopod diversity to faunal replacements during the period that the limestone was deposited. Another possibility is that Stevens' (1971) correlation of brachiopod diversity and depth is not completely reliable.

The Shumway limestone appears to have been deposited in a complex environment with both plant growth and patches of bare, fairly soft substrate. More complex environments may provide habitats for species that in less complex environments could not coexist. One indication that this might be the case may be found in the relationship of the Shumway fauna and Johnson's (1962) associations. The Shumway fauna incorporates most elements of both the Chonetina and Gastropod associations. If these associations are correlated with substrate as Johnson (1962) implies, then it is reasonable to expect elements of both associations to be present in areas where both substrates exist. There is no reason to believe that intermediate or mixed habitats should occur at depths greater than the individual habitats. Stevens' (1971) correlation between brachiopod diversity may in some cases be appropriate but application of the hypothesis without some independent means of confirmation is not wise. Brachiopod diversity may be especially misleading where a complex environment is indicated by the pelecypod and gastropod faunas.

Trophic level analysis in the sense of Walker and Laporte (1970) and Walker and Bambach (1974) cannot be performed since no attempt was made to quantify the relative abundance of each taxon. As in other Paleozoic faunas reviewed by Walker and Laporte (1970) and Bretsky (1969) suspension feeders dominate the fauna. Like other open shelf environments (Bretsky, 1969), brachiopods are the most common and diverse suspension feeders.

SUMMARY

The Shumway limestone appears to have been deposited in shallow, quiet water. Plants were apparently an important component of the biota and may have provided attachment sites for smaller byssate pelecypods and pedunculate brachiopods and possibly provided food for certain of the gastropods. The substrate was relatively soft allowing infaunal pelecypods to inhabit the area. Bare spaces between the plants were occupied by productid brachiopods of several genera, free lying brachiopods and occassionally by larger pedunculate brachiopods and byssate pelecypods in areas where the bottom was locally firmer.

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CHARACTERISTICS OF ULTRAVIOLET LIGHT-INDUCED AUXOTROPHS IN SACCHAROMYCES CEREVISIAE

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ABSTRACT

UV-induced auxotrophs of Saccharomyces cerevisiae S288C have been studied by reversion tests with ICR-170, MNNG, EMS, and UV. The results show that UV produces both base-pair substitution and frameshift mutations in this eucaryote. In addition, some mutants are reverted strongly by UV but not by chemical mutagens used.

INTRODUCTION

Mutations at the cellular level may be classified into two categories: macrolesions and microlesions. Macrolesions consist of gross chromosomal changes including extended deletions, duplications and rearrangements of portions of chromosomes. Microlesions consist of changes at the molecular level and include base-pair substitution mutations and frameshift mutations. Base-pair substitution mutations may arise by the substitution in DNA of one nitrogenous base-pair by another nitrogenous base-pair, and may result in the insertion of a different amino acid at a given point in a polypeptide after translation. Frameshift mutations result from the addition or deletion of one to a few base-pairs in the DNA (Brenner, 1961). The mutations cause a shift in the reading frame starting from the point of insertion or deletion of the base(s).

Ultraviolet radiation (UV) has been widely used to induce mutations in many biological systems from bacteriophage to mammals (Altenberg, 1930; Bridges, 1970; Drake, 1970; Holmberg, 1974; Morris, 1974; and Witkin, 1969). To date, however, the mechanism of UV-induced mutations is not well understood, although certain major molecular lesions, such as pyrimidine dimers, and their fate are now recognized (Setlow, 1963; Swenson, 1966; and Witkin, 1969). In Salmonella typhimurium and Escherichia coli, UV induces frameshift mutations as well as base-pair substitution mutations (Berger, 1968; and Kanazir, 1970). Recently, molecular characterization of UV-induced mutations has been performed in Neurospora crassa (Kilbey, 1971). This study describes the mutagenic characteristics of UV in the induction of auxotrophic mutations in strain S288C of Saccharomyces cerevisiae.

MATERIALS AND METHODS

Cultures and Mutagens: The haploid strain of S. cerevisiae S288C was used for induction of auxotrophs by UV. Wildtype cells of this culture grow well on minimal medium (Magni, 1962).

A General Electric 15-W germicidal lamp (GT 1578) with 95% of its energy in the wavelength 254 nm was the source of UV radiation. The dose rate was $4.4/mm^2$.sec as measured by a Jagger meter (Jagger, 1961). 2-Methoxy-6-chloro-9-[3-(ethyl-2-chloroethyl)aminopropylamino] acridine. 2 HCL (ICR-170) was obtained from Dr. H. Creech of the Institute for Cancer Research, Philadelphia, PA. N-Methyl-N'-nitro-N-nitrosoguanidine (MNNG) was purchased from Aldrich Chemicals, Milwaukee, WI, and ethyl methanesulfonate (EMS) was purchased from Eastman Chemicals, Rochester, NY.

Preparation of Cells for Forward Mutation and Survival Curve Analyses:

Cells grown on complete agar plates (Pittman, 1971) for 24 hr were harvested and inoculated into 10 ml of complete nutrient broth (Pittman, 1971) at a final concentration of 1 to 2 x 10^4 cells/ml, as determined by hemocytometer counts. The resulting culture was shaken for 12 hr or 72 hr to give one log-phase culture and one stationary-phase culture.

UV Treatment for Survival and Forward Mutation Analyses: Five ml of culture suspension (10^6 cells/ml) were put into the petri dish positioned on a magnetic stirrer. The suspension was stirred. Control samples were removed, and the suspension was irradiated with UV at intervals of 15 sec. After each exposure, an aliquot was removed and diluted to give approximately 100 viable units per plate. Aliquots of the appropriate dilution were plated immediately on complete agar plates. Colony counts were made after the plates had incubated for 48 hr.

Isolation of Mutants and Test of Nutritional Requirements of Mutants:

Auxotrophic mutants were isolated by Replica Plating Methods (Lederberg, 1952). Confirmed mutants were stored at 5°C on complete nutrient agar slants. For test of nutritional requirements, small samples of mutants were spotted by a loop on complete agar at about 40 different mutants per plate. Plates were incubated for 24 hr and replica plated on minimal agar plates, each supplemented with a specified amino acid or with adenine; minimal agar plates; and complete agar plates. Mutants were scored for nutritional requirements after 48 hr incubation.

Reverse Mutation Analyses: (A) UV: Mutant strains were plated on enriched minimal agar plates (0.02 g Difco-nutrient broth/ 1 of minimal agar). Plates were treated with UV for 15 sec since experiments with 3 auxotrophs showed that this dose produced the highest number of revertants. Revertants were scored after plates had incubated for 4 days. (B) Spot Test: Cells were prepared on enriched minimal agar plates. A 0.1 ml aliquot of a designated mutagen was dropped on the center of each plate. The plates were incubated for 7 to 10 days then scored for revertants.

RESULTS AND DISCUSSION

Figure 1 shows the sensitivity of log- and stationary-phase yeast cells to killing by UV. The survival curve of log-phase cells showed an inflection at about 25% survival, indicating a heterogeneity of the population to UV killing. This inflection was not seen with stationary-phase cells, and stationary-phase cells were more sensitive to UV. Due to the population homogeneity and high UV sensitivity of stationary-phase cells, this population was used to obtain UV-induced mutants. A total of 122 auxotrophs were isolated from UV-treated cells (at survival levels from 31% to 39%) and tested for their nutritional requirements. The results are shown in Table 1. Of the 122 mutants studied, 33 grew on complete nutrient agar but not on any of the 13 minimal agar plates that were supplemented with a single amino acid or adenine. Methionine mutants occurred with the highest frequency; mutants were also found for arginine, histidine, lysine, threonine, isoleucine, tryptophan, and adenine. Three mutants grew on either anthranilic acid or tryptophan. No mutants were observed that required only phenylalanine, glycine, or proline for growth.

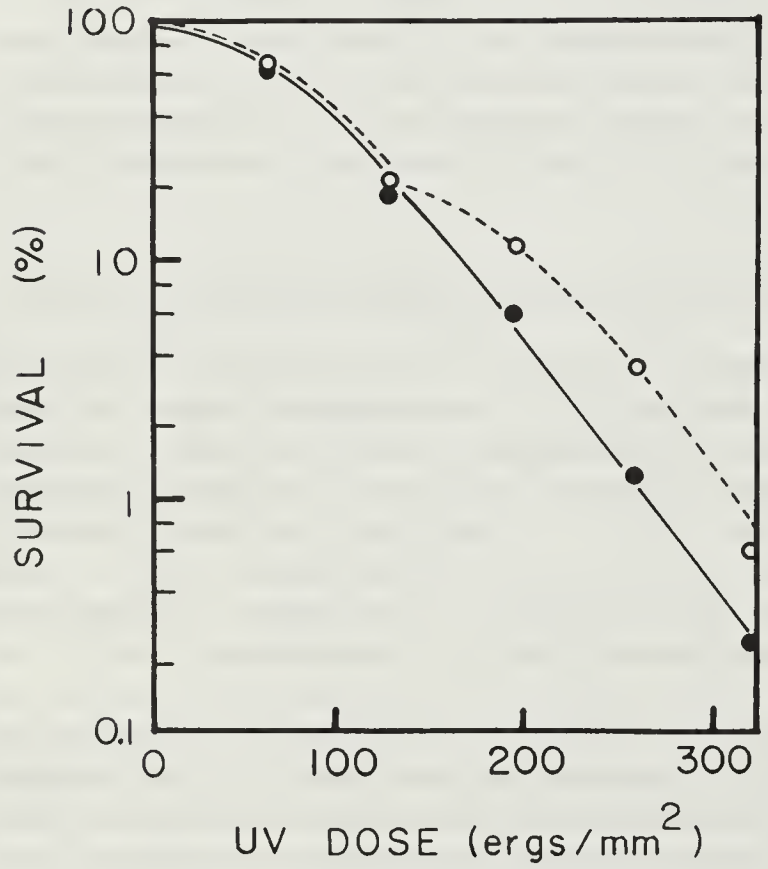

Figure 1. Survival curves of UV-irradiated log- and stationary-phase yeast cells. Cells were starved for 12 hr in 0.1 M phosphate buffer (pH 7) before UV treatment. o--------o, log-phase cells; ●————●, stationary-phase cells.

Table 1. Nutritional requirements of 122 UV-induced mutants

Nutritional Requirement	Number of Mutants
Methionine	24
Arginine	13
Histidine	13
Lysine	10
Threonine	2
Isoleucine	1
Tryptophan only	9
Tryptophan or anthranilic acid	3
Phenylalanine	0
Glycine	0
Leucine	0
Proline	0
Adenine	14
Others	33
TOTAL	122

Small samples of different mutants were spotted by a loop on a complete agar plate and incubated as described in Methods. After incubation at 30°C for 24 hr, the samples were replica plated onto minimal agar plate supplemented with a specific amino acid (0.03 mg/ml) or with adenine (0.05 mg/ml). The growth patterns were compared with samples replica plated onto minimal agar plate.

Of 122 UV-induced mutants, 26 showed no spontaneous reversion (detectable at approximately 10^8 cells per plate), and the remaining 96 mutants gave a spontaneous reversion frequency over a rather large range of one to hundreds of revertants per plate. Some of the mutants were slightly leaky, but the spontaneous revertants from these mutants could still be observed.

All UV-induced auxotrophs were tested for their reversion patterns with ICR-170, MNNG, EMS and UV. ICR-170, MNNG, and EMS are mutagens routinely employed by investigators to determine the molecular basis of mutations induced by different physical or chemical agents. In practice, most of the mutagens fail to show high specificity (Prakash, 1973). For example, MNNG and EMS are believed to induce and revert base-pair substitution mutations (Adelberg, 1965; Drake, 1970; Eisenstartk, 1965; and Yanofsky, 1966), but occasionally they may also induce frameshift mutations (Funatsu, 1964; Malling, 1968; Pittman, 1971; and Yourno, 1969_b). ICR-170 induces predominantly frameshift mutations, and may or may not revert frameshift mutations (Oeschger, 1970; Whitfield,

1966). There is no direct biochemical evidence presently available which shows that ICR-170 has the ability to revert base-pair substitution mutations. In the present study, the following operational definitions are used in the classification of UV-induced mutations: (1) mutants that were reverted by ICR-170, whether or not they were reverted by MNNG and/or EMS, were classified as frameshift mutants, (2) mutants that were reverted by MNNG and/or EMS but not by ICR-170 were classified as base-pair substitution mutants. Using these definitions, the 122 UV-induced auxotrophs were classified as shown in Table 2. Of the total mutants induced by UV, 10 (8%) were reverted by ICR-170 and were therefore classified as frameshift mutants. Of these 10 mutants, 9 were also reverted by UV. Of the remaining mutants, 55 (45% of the total) were reverted by MNNG and/or EMS but were not reverted by ICR-170, thereby classifying them as base-pair substitution mutants. Of these 55, 53 were also reverted by UV. Fifty-seven of the mutants were not reverted by any of the chemical mutagens. Thirty-nine (32% of the total) of 57, however, were reverted by UV alone. Of the 18 (15% of the total) mutants that could not be reverted by the 4 mutagens used, 6 exhibited spontaneous reversion, and therefore were considered to be point mutants. The final 12 mutants were neither reverted spontaneously nor by any mutagen used. These mutants, therefore, were assumed to result from large deletions, multiple point mutations, or a class of extremely stable point mutations (Brusick, 1972).

Table 2. Reversion analysis of 122 UV-induced mutants with UV, ICR-170, MNNG, and EMS

Reversion Pattern	Number of Mutants	Percent of Total Mutants Tested
UV, ICR-170, MNNG, and/or EMS	8	6.4
UV, ICR-170	1	0.8
ICR-170, MNNG	1	0.8
	10	8.0
UV, MNNG and/or EMS	53	43.4
MNNG and/or EMS	2	1.6
	55	45.0
UV	39	32.0
No induced reversion	18	15.0

Methods for reversion analyses are stated in Methods section.

Of the 65 mutants classified by the chemical mutagens as base-pair substitution or frameshift mutations, 62 were reverted by UV. This result indicates that UV can efficiently revert both base-pair substitution and frameshift mutations. Of the remaining 57 unclassified mutants, 39 could be reverted by UV. Hence, 101 out of 122 UV-induced mutants were reverted by UV. The high efficiency of UV reversion of UV-induced mutants of S. cerevisiae may be partially explained by the induction of suppressors (Yourno, 1969_a) or by sites that are hotspots (Benzer, 1961) for UV mutation.

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FATTY ACIDS OF MYCOBACTERIUM SMEGMATIS LIPIDS

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ABSTRACT - Thin-layer chromatography was applied to the resolution of Mycobacterium smegmatis lipids and the fatty acids of the glycerides, the waxes and esterified components and the free fatty acids were analyzed. By gas chromatography-mass spectrometry, 10-methyloctadecanoic acid was identified in the fractions as well as in the total saponifiable portion of the lipids and was especially prominent in the free fatty acids, diglycerides and in the phospholipids. Cyclopropane fatty acids could not be detected in any of the lipids.

The lipids of Mycobacterium tuberculosis have been widely studied and several of the approaches extended to other virulent forms and to saprophytic mycobacteria. Thin-layer chromatography (TLC) of components as well as the differentiating characteristics of the fatty acids have been applied as aids to the classification of mycobacteria. Acetate incorporation into the fatty acids has been shown to increase markedly in the presence of other acids in various mycobacteria (Bekhtereva et al., 1971; Kanemasa and Goldman, 1965; McCarthy, 1971; Weir et al., 1972), the latter workers reporting a rapid incorporation of tracer levels of oleic acid into the triglycerides of M. smegmatis. The positional distribution of fatty acids in the triglycerides and phospholipids of mycobacteria has been determined (Okuyama et al., 1967; Walker et al., 1970). The fatty acid composition was found to be a function of the age of the mycobacterial cells in two virulent strains and two saprophytes screened, one of the latter being M. smegmatis (Chandramouli and Venkitasubramanian, 1973). The unsaturated and branched fatty acids noted with these saprophytes followed the distribution in M. tuberculosis (Bennet and Asselineau, 1970), M. album (Gerasimova et al., 1970), M. phlei (Lennarz et al., 1962; Ciarlini et al., 1964; Campbell and Naworal, 1969). 10-Methyloctadecanoic acid (19Br) has been found in the fatty acids from 90 strains of mycobacteria, of which twenty-five were atypical (Lucchesi et al., 1967).

The present study was undertaken to discern fatty acid profiles of lipid components of M. smegmatis separated by TLC, emphasis being directed to the waxes, glycerides, free fatty acids and the phospholipids and to the distribution of 19Br. A search for cyclopropane fatty acids was also instituted. Previously, the fatty acids of M. smegmatis tri-

glycerides and phospholipids were analyzed and several unsaturated fatty acids identified (Walker et al., 1970; Hung et al., 1970). The phospholipid content of this organism has been followed by use of TLC and tracer techniques (LaBelle and Walker, 1972). M. smegmatis has also been investigated in relation to mannophospholipids (Takayama et al., 1973), transacylases (Berset and Étemadi, 1973; Josse et al., 1973) and the mycolic acids (Asselineau and Bennet, 1964; Étemadi and Lederer, 1965; Étemadi and Pinte, 1966; Goren, 1972).

MATERIALS AND METHODS

Redistilled AR grade solvents were employed and all glassware was rinsed copiously with ether and chloroform-methanol (2:1 by volume). Concentration of fractions was carried out under vacuum or nitrogen and the samples were stored at 4° under nitrogen. M. smegmatis (ATCC 10143) was cultured in a Dubos-type medium (30 g tripticase soy broth (BBL), 7 g Dubos broth base (Difco), 10 ml glycerol and 1 liter deionized water) and the initial inoculum prepared by inoculating 150 ml of medium with a loopful of bacterial cells from an agar slant. The flasks which were placed in a rotary shaker for 72 hr at 32° comprised the inoculum for the larger flasks. The large batches of cells were prepared in 2 liter Erlenmeyer flasks containing 500 ml of culture medium and each was inoculated with 0.2% by volume of the growth from the initial inoculum flask. The flasks were incubated for 3 days at 32° on the shaker, after which time, the cells were filtered by centrifugation and washed twice with water; the thick paste was dried at 25°. A total of six different runs was made involving 208 flasks and of these, seven were discarded due to contamination which could be detected by appearance and odor. The total weight of dried cells was 700 g. When 420 g of cells was extracted in a Soxhlet assembly with ethyl ether, then with 2:1 v/v chloroform-methanol, the residues weighed 14.48 and 0.48 g, respectively. Extraction of the combined product with warm n-hexane gave rise to 5.09 g (34.1%) of lipids.

Separation of lipids by TLC was effected by the procedure advanced by this laboratory (Singh et al., 1965). By use of 98% acetone + 2% petroleum ether (b range 30-60°), 4 fractions were obtained, the least mobile one (I) containing the phospholipids, (II), the free fatty acids and among other components, (III), the wax esters and the nonfree fatty acids (mainly fatty alcohol esters) and fraction IV, the mono-, di- and triglycerides. Further resolution of fraction IV was accomplished by TLC employing 1-butanol saturated with water and of fraction III, by two-dimensional TLC with 95% ethanol in the first direction and chloroform in the second. The presence of glycerides was confirmed by IR analysis. An aliquot of the bacterial lipids was saponified with 20% sodium hydroxide in 95% ethanol according to the procedures detailed earlier (Gershbein et al., 1965; Gershbein and O'Neill, 1966; O'Neill and Gershbein, 1976); the unsaponifiable portion comprised 62% of the total lipids. The fatty acids were processed and converted to methyl esters by refluxing with methanol saturated with hydrogen chloride. The latter treatment was also accorded the phospholipids, the least mobile fraction in the TLC separation, following hydrolysis with acid in sealed tubes (Dawson, 1960; Singh and Gershbein, 1967) and the glycerides, after transesterification (Luddy et al., 1960).

For GC, a Loenco model 70, Hi-Flex gas chromatograph with dual hydrogen flame detectors was used; the packing was 3 wt% SE-30 on 120-130 mesh Anakrom ABS. Temperature programming was conducted over a range of 150° to 325°, isothermal operation being applied at the conclusion of the run until elution of the desired range of components had occurred. Standard mixtures were used for identification of the acids and where the components did not correspond to the saturated straight chain esters, these were given in terms of the fractional equivalent chain length (ECL). For GC-MS, a Hitachi Perkin Elmer model RMU-6D focusing spectrometer was utilized in conjunction with a Perkin Elmer model 881 gas chromatograph with a dual hydrogen flame ionization detector. The packing was 3 wt% methyl silicone (OV-I) in this case. The latter was employed in relation to the branched acids and a Varian model A-60 spectrometer, in conjunction with the cyclopropane fatty acids, a characteristic peak at 0.65 ppm being screened.

RESULTS AND DISCUSSION

Hexane was employed in the extraction of the crude mixtures as it removed lipids of lower polarity, thereby circumventing several of the conjugated polar types. The hexane-extracted lipids (545 mg) on dilution with 40 ml of ethyl ether deposited insoluble material (71.5 mg) on storage at 0° for 12 hr. The resulting filtrate on TLC fractionation gave rise to the analytical data presented in Table 1; the overall recovery was 86%. The order of increasing occurrence of the glycerides was: tri- > di- > mono-; the phospholipid and fatty acid portions were relatively high, constituting 18.1 and 9.8%, respectively. The esters and waxes accounted for 40.2% of the total lipids.

The distribution of fatty acids in the glycerides, wax esters, phospholipids and in the free and total acid mixtures is shown in Table 2. Cyclopropane fatty acids could not be detected in any of the products. A GC tracing is exemplified by the free fatty acid mixture in Figure 1. The latter displays unlabeled peaks of retention times shorter than C_{14} and represnet lower carbon chain fatty acids. These were not quantitated due to possible losses on volatilization during isolation. The patterns revealed the presence of a unique component exhibiting an ECL of 18.54. By MS, the acid displayed a small peak at m/e 171 (with rearrangement peaks at m/e 172 and 173) and strong peaks at m/e 199 and m/e 167. The latter results from removal of methanol (m/e 32) from the m/e 199 peak. The fragment distribution pattern was identical with the spectrum reported by Ryhage and Stenhagen (1960) for 19Br. The latter occurred to the extent of 7.5, 9.8 and 21.4% in the diglycerides, phospholipids and free fatty acids, respectively and comprised less than 1-2% of the other TLC fractions. It made up 16.3% of the total lipid saponifiable portion where it ranged second only to hexadecanoic acid (31.0%). The 18:0 acid was prominent in most lipid classes, especially in the esterified or wax components. Both the 16:1 and 18:1 acids generally ranged low but were elevated in the phospholipids and waxes. The acid, 24:0, was prominent in the di- and triglycerides and the phospholipids. The high level of the 19Br or of the acids in general in the free fatty acid portion may stem from an elevated phospholipase activity of the organism although data of this type were not obtained in the present study.

Table 1. Partial Analysis of M. smegmatis Lipids by TLC[a]

Fraction	Identification	Recovery mg	Recovery %
I	Phospholipids	73.3	18.1
II	Free fatty acids	39.8	9.8
V	Triglycerides	34.0	8.4
VI	Diglycerides	24.0	5.9
VII	Monoglycerides	9.8	2.4
X	Wax esters	21.2	5.2
XI	Nonfree fatty acids	142.0	35.0

[a] The recoveries are based on the respective weights of fractions isolated from the TLC plates.

A few discrepancies exist in the levels of the C_{16} and C_{18} acids among the phospholipids and triglycerides as compared to the findings of Walker et al. (1970) with the same strain of M. smegmatis but in the stationary phase of growth. However, different culture media were employed and variations may arise in the age of the cells harvested coupled with the differences in the experimental technique. Furthermore, the lower levels of some of the homologs may reside in the rapid uptake or utilization of the acids by the organism. The current data with the cells in the mid-log phase of growth, also show some similarity to the total acids from the organism employed by Chandramouli and Venkitasubramanian (1973), M. smegmatis (NCTC London). The latter workers observed that 19Br was the major acid at the third day of growth and a decrease in 18:1 resulted with a concomitant elevation in 19Br with culture age. The higher 16:1 content differentiated the organism from virulent strains.

The significant occurrence of the 19Br in the diglyceride and phospholipid fractions identifies the precursor relationship of the two classes and supports the findings of Zalkin et al. (1963) that in cyclopropane fatty acid formation, the phospholipid is the preferred substrate. The methyl group of the 19Br arises from methionine and the enzymatic synthesis of 19Br and the cyclopropane fatty acid has been studied by Akamatsu and Law (1968).

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The authors are indebted to Dr. W. E. Grundy of Abbott Laboratories, North Chicago, Illinois, for his untiring aid in the culturing of the bacterial cells and to Dr. R. G. Scholz for assistance in the mass spectrometry.

Table 2. Relative Weight Percentages of Fatty Acids of Various Lipid Classes from TLC Fractionation of *M. smegmatis*

(SE-30) ECL[a]	Total acids[b]	Mono-glycerides	Di-glycerides	Tri-glycerides	Phospho-lipids	Free fatty acids	Nonfree fatty acids	Wax esters
13.84	0.36	1.1	2.5	1.3	1.8	0.07	2.5	3.9
14.00	3.9	6.8	5.0	3.9	2.9	3.7	16.7	2.6
.25	-	-	-	-	-	0.48	-	-
.54	0.39	1.0	0.70	-	0.22	0.20	-	0.34
.67	-	1.2	0.61	3.3	-	-	-	0.91
.74	0.24	-	-	-	0.52	0.29	0.30	-
.90	-	1.8	-	-	0.59	-	0.20	-
15.00	2.4	3.5	1.8	1.7	0.52	0.25	0.83	1.5
.08	-	-	-	7.2	-	1.5	-	-
.25	-	-	1.5	-	0.82	-	2.8	-
.33	-	-	-	0.61	-	0.13	-	-
.54	-	1.2	0.70	2.8	-	0.40	-	-
.74	2.2	-	2.8	2.0	5.4	-	7.0	2.7
16.00	31.0	28.3	31.8	32.4	21.4	29.2	22.3	20.5
.33	-	0.29	-	-	-	-	-	-
.54	2.6	0.21	1.2	4.6	1.8	1.5	0.49	0.32
.74	-	-	-	-	0.89	0.20	0.83	4.4
17.00	1.2	4.7	1.7	2.6	1.3	0.75	0.99	7.1
.25	-	0.62	-	-	-	0.22	-	1.1
.56	0.56	0.95	0.47	2.4	-	2.1	-	-
.74	9.5	2.7	1.4	0.52	24.2	-	11.1	7.8
18.00	7.6	8.3	10.7	5.4	7.0	4.9	17.1	10.2
.54	16.3	0.54	7.5	1.5	9.8	21.4	0.81	0.84
19.00	2.6	2.3	2.3	1.3	1.0	1.4	1.1	2.8
.54	0.78	0.95	1.4	1.5	-	14.6	-	0.25
.74	-	-	-	-	1.0	-	0.94	1.1
.85	0.89	-	-	-	0.30	-	3.8	1.1
20.00	0.78	2.5	3.9	2.0	0.48	0.60	0.50	6.9
.54	0.53	4.1	0.25	0.92	0.12	0.88	-	0.30
.74	0.63	0.21	-	-	-	-	-	0.25

Table 2. Concluded

(SE-30) ECL[a]	Total acids[b]	Mono-glycerides	Di-glycerides	Tri-glycerides	Phospho-lipids	Free Fatty acids	Nonfree fatty acids	Wax esters
21.00	-	3.1	0.94	0.92	0.55	2.6	1.0	2.2
.25	1.6	-	-	1.8	-	3.2	-	-
.64	-	1.9	2.6	0.92	0.52	-	0.80	-
22.00	1.4	5.8	4.5	2.4	1.9	1.8	3.1	11.8
.33	-	3.7	-	-	-	0.21	-	-
.54	-	-	0.17	0.22	-	-	-	-
.74	0.12	-	-	-	-	0.03	-	-
23.00	0.01	0.82	0.40	0.22	0.22	0.05	0.80	1.4
.33	0.06	-	-	4.2	-	1.1	-	-
.64	-	2.1	0.14	-	0.15	0.26	0.46	1.0
24.00	12.1	3.5	11.3	7.7	14.6	1.6	2.3	3.3
.26	-	0.31	-	0.39	-	-	-	-
.64	-	3.0	-	0.39	-	1.1	-	-
25.00	0.05	2.0	0.28	0.74	-	0.08	0.66	2.8
.54	-	-	-	1.7	-	-	-	-
26.00	0.07	0.50	1.2	0.74	-	3.2	0.33	0.59

[a] The integral part of the equivalent chain length, ECL, identifies the lower carbon number of the homologous series of fatty acid esters and the fractional portion refers to the relative retention time (position) between an ester and the next higher homolog.

[b] Mixture from saponification of the initial lipids with alcoholic alkali.

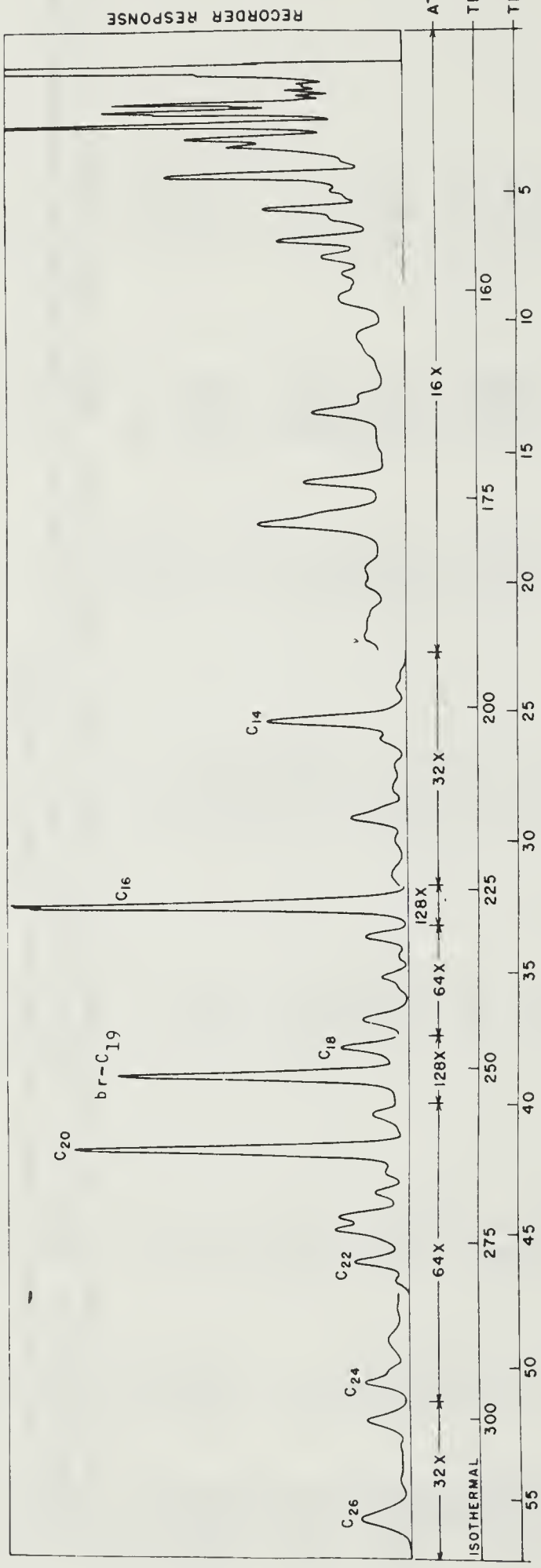

Figure 1. Gas chromatographic separation of methyl esters of M. smegmatis free fatty acids on SE-30.

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STRAIN DIFFERENCES IN DISTRIBUTION CURVES IN RESPONSE TO SELECTION FOR EARLY PUPATION TIME IN *TRIBOLIUM CASTANEUM*

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ABSTRACT

Selection for early pupation time was performed for six generations in two genetic strains (antennapedia and Purdue + Foundation) of *Tribolium castaneum*. Total response to selection was -0.5 days for the S+ line and -1.3 days for the S*ap* line. Realized heritabilities of 0.09 ± 0.08 for S+ and 0.15 ± 0.08 for S*ap* were calculated as a measure of the effectiveness of selection.

Both the S+ and C+ lines exhibited a bimodal distribution curve for developmental time, which was maintained throughout the selection experiment, while the S*ap* and C*ap* lines exhibited a unimodal distribution.

INTRODUCTION

Developmental time is considered as one of the important components of fitness for the flour beetle, *Tribolium castaneum,* and has been shown to be under genetic control (Dawson, 1965; Englert and Bell, 1964, 1970; and Scheinberg *et al.*, 1967). In each of these studies, however, examination of the genetic control through selection pressures was restricted to a single broad-based genetic strain.

The purpose of this study was to examine the response to selection for early developmental time (pupation time) in two different genetic strains of *T. castaneum,* and to compare the response differences that might occur.

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MATERIALS AND METHODS

The selected lines were initiated using two noninbred, mass-mated stocks of *Tribolium castaneum:* antennapedia, *ap,* (Englert and Bell, 1963a) and the Purdue + Foundation stock (Bray *et al.*, 1962). Both had been shown to have equivalent pupation times when not under selection and when genetic backgrounds were similar (Englert and Bell, 1963b). For the present study, two lines were derived from each population, one selected for early pupation time (S+ and S*ap*) and the other a control subjected to stabilizing selection (C+ and C*ap*). All lines were reared in a darkened Lab-line incubator, Model No. 844 II, maintained at 33 ± 1°C and 50 ± 10% R.H.

Base populations for each strain were established by mass mating several hundred adults taken from three different culture bottles. The mass matings were placed into plastic boxes (17.8 x 12.7 x 6.2 cm) containing 100 gm standard medium (95% whole wheat flour and 5% dried brewer's yeast) for 24 hours. The progeny from this egg collection were then used to start Generation O for each selected and control line by placing 100 adults randomly selected from the population box into a glass baby food jar (9.8 x 6.3 cm) containing 24 gm standard medium for two successive 12-hr egg collections.

At 12 days of age (Day O being the day parents were set for egg collection) 100 larvae were randomly selected and placed individually into 20 ml glass creamers containing approximately 0.1 gm standard medium. On Day 15, checks for pupation were initiated and continued every 12 hr until all larvae had pupated or until Day 26, when all remaining larvae were discarded to keep the lines within the same generation cycle; however, no larvae were discarded during any generation of selection. The first group to be measured constituted the generation prior to the initiation of selection, Generation O.

For both selected lines the fourteen fastest pupating females and six fastest pupating males (selection intensity of 20%) were chosen as parents for the next generation. In the control lines, the fourteen females and six males whose individual pupation times were at or near the mean pupation time recorded for the line during the current generation were selected. When more than the required number qualified for selection as parents, individuals were randomly chosen. The first group of selected individuals constituted the parents of Generation 1, and the method used to select each group of parents was practiced in all subsequent generations.

The twenty selected parents were allowed to mature as adults for eight days, and then were mass mated for two days in 20 ml grass creamers containing 4 gm standard medium after which two successive 12-hr egg collections were made. Procedures used in Generation O for measurement of the trait being selected were repeated in all subsequent generations. Selection was practiced for six generations.

Due to space and time limitations, the selection programs of the two genotypes were not initiated concurrently. The C*ap* and S*ap* lines were chronologically one generation behind the C+ and S+ lines. At Generation

3 for the + lines and Generation 2 for the *ap* lines, extreme difficulty was experienced in maintaining consistent humidity levels; this difficulty was minimized during subsequent generations.

RESULTS

The results of six generations of selection for early pupation time are given in Figure 1. Developmental times of the + Foundation Population and the *ap* strain were found to differ from each other before selection was

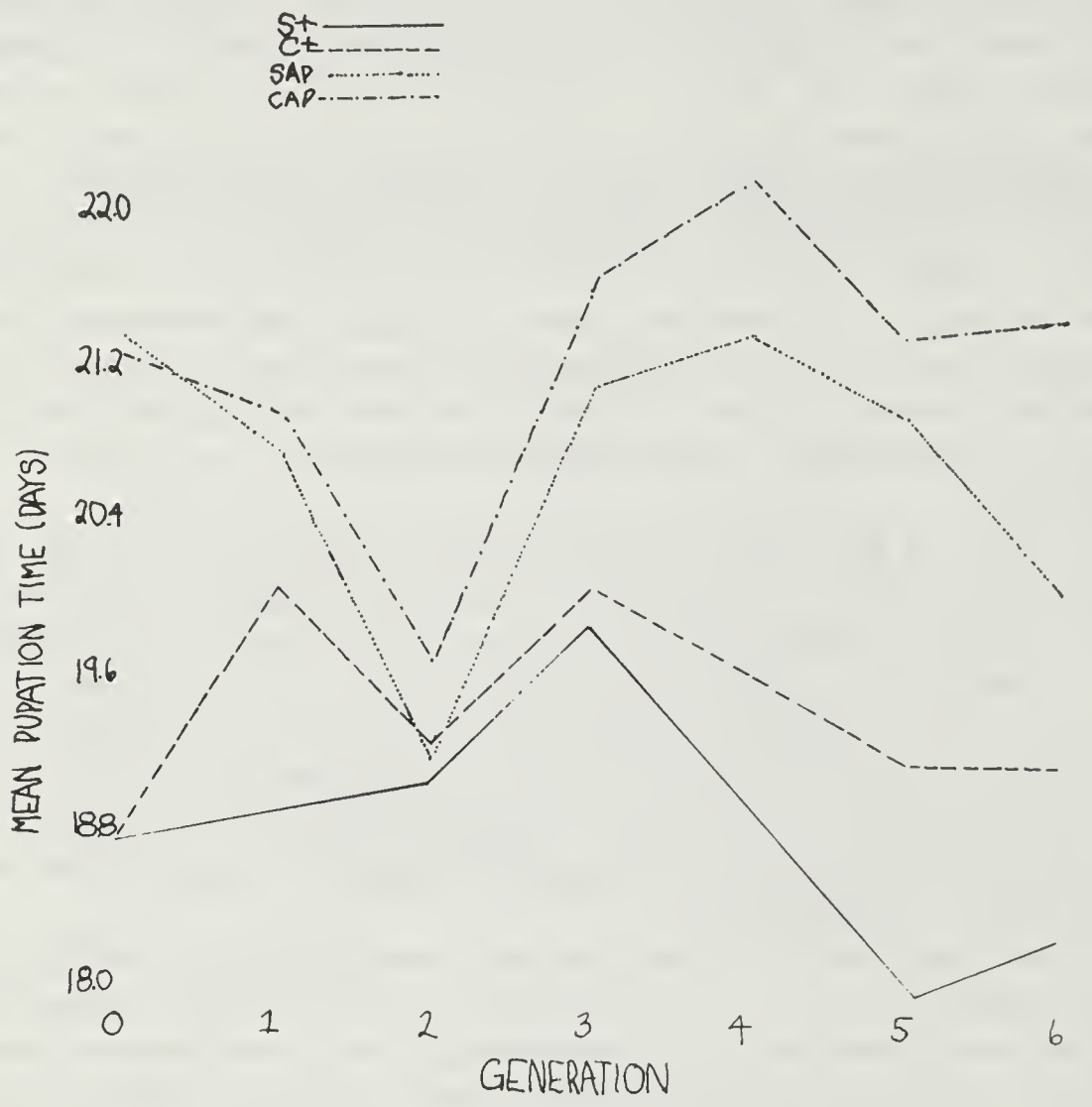

Figure 1. Response to selection for early pupation time by two genetic strains of *Tribolium castaneum*.

initiated, with means of 18.8 ± 0.14 days and 21.4 ± 0.13 days for + and *ap*, respectively at Generation 0. These differences between strains were maintained throughout the study. An earlier study (Englert and Bell, 1963b) had indicated that pupation time of the *ap* strain was equal to that of the + Foundation Population when a common genetic background was present. However, since its origin, the *ap* strain had been maintained as a closed population and divergence over time may well account for the differences observed.

Total response over six generations of selection was observed to be greater for the S*ap* line than for the S+ line, -1.3 and -0.5 days, respectively. However, when calculated in terms of the deviation from the control, the average change in pupation time per generation was -0.2 days for the S+ line and -0.1 days for the S*ap* line. The effectiveness of selection, measured in terms of the realized heritability (Falconer, 1960) for S*ap* was 0.15 ± 0.08 and for S+ was 0.09 ± 0.09. These estimates are not significantly different.

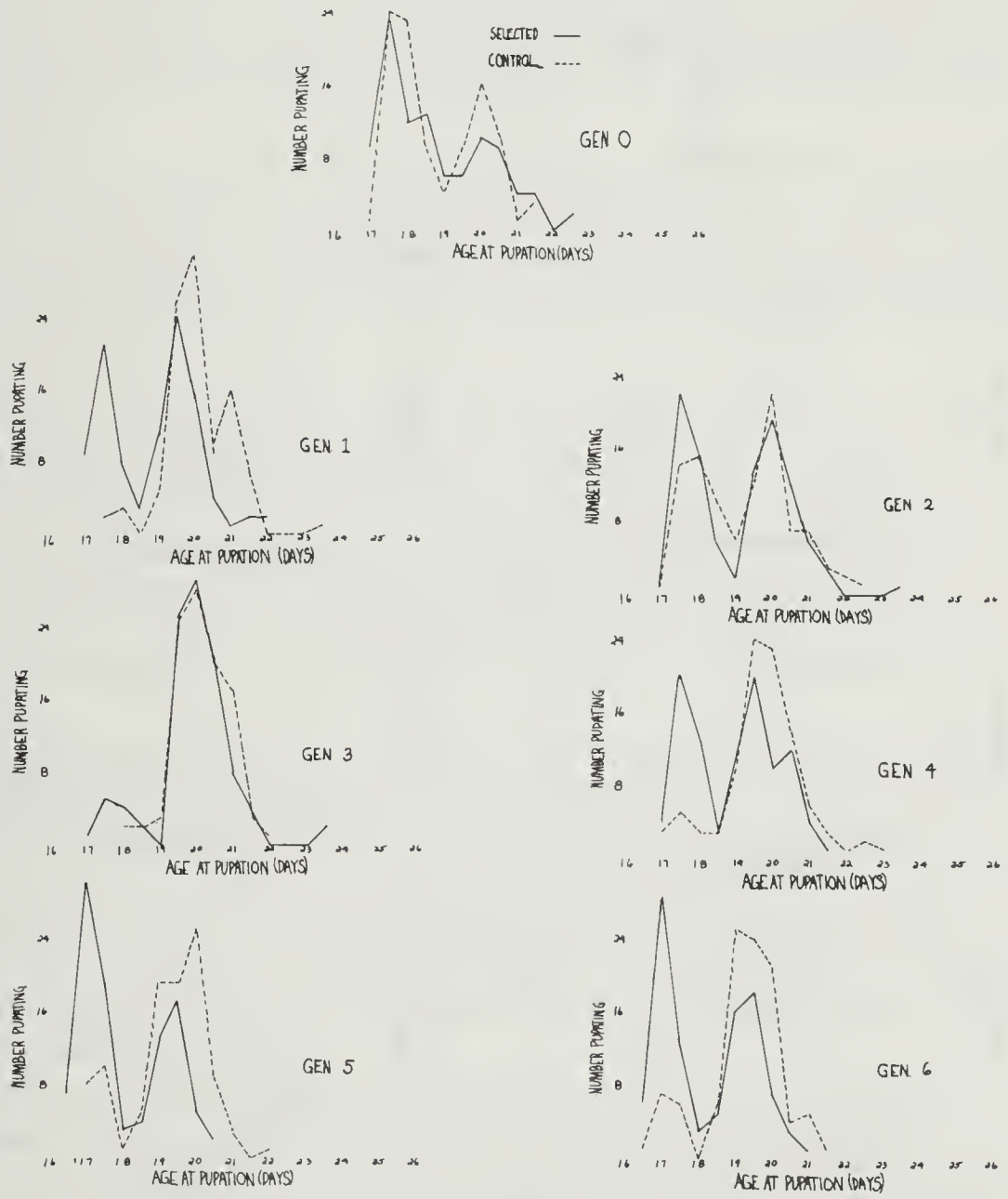

Figure 2. Distribution curves of pupation time for the selected and unselected lines of wild-type.

An examination of the selection differentials and the phenotypic variances, upon which the realized heritabilities are dependent, proved also not to differ significantly. The selection differentials of the S+ line were slightly larger than those for the S*ap*, averaging -1.38 for the former and -1.20 for the latter. The phenotypic variances for both selected lines, S+ and S*ap*, were found to decrease as selection was practiced, going from 1.80 to 1.17 for S*ap* and 2.02 to 1.53 for S+ over the six generations of selection. Since

response, though limited, was still being observed in Generation 6, the decrease in variance was most likely associated with a reduced environmental variance.

The frequency distribution curves showing the number of larvae pupating in 0.5 day intervals for each generation of selection are presented for the + lines in Figure 2 and the *ap* lines in Figure 3. The + Foundation lines, at Generation 0 and all subsequent generations of selection except Generation 3, exhibited a bimodality in the frequency distribution curves for deve-

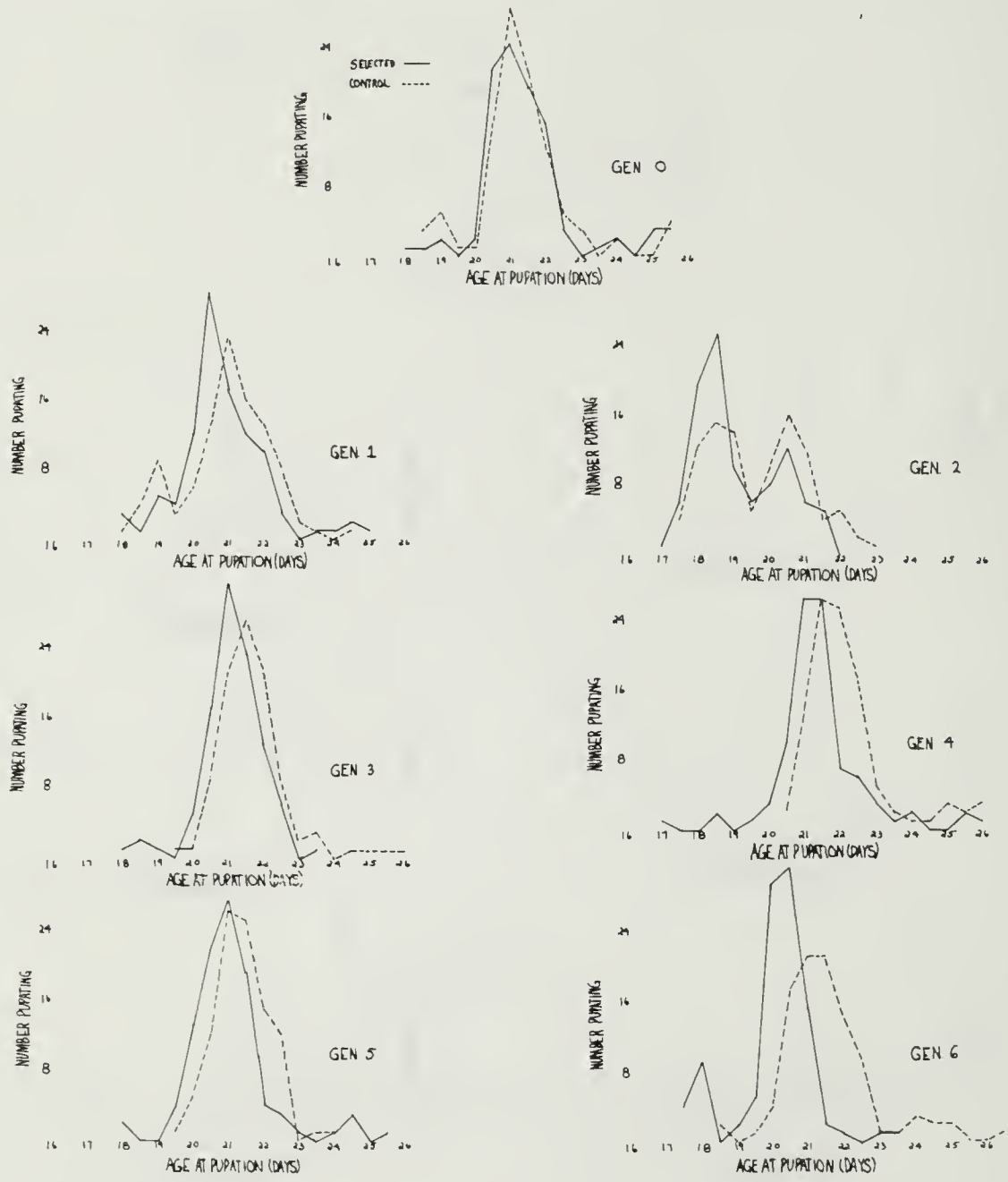

Figure 3. Distribution curves of pupation time for the selected and unselected lines of antennapedia,

lopmental time. In contrast, the *ap* lines exhibited unimodality in the frequency distribution curves of each generation except Generation 2 (Figure 3). The difficulty in maintaining consistent levels of humidity apparently made its effects most pronounced, and the two strains reacted quite differently to the environmental stress placed upon them. No significant differences in distribution between sexes were observed for either strain, al-

though males generally were earlier pupators, but not significantly so. Within each strain, the selected and control lines responded similarly during this stress period.

DISCUSSION

Successful selection for early pupation time, or fast development, in *Tribolium* has also been reported by other workers (Dawson, 1965; Englert and Bell, 1964, 1970; Scheinberg *et al.*, 1967; Soliman 1974; Wool, 1969), and the realized heritability estimates observed for this study are in general agreement with those reported in the earlier studies, although the standard errors calculated are large, and possibly biased downward due to the inevitable presence of genetic drift present in the small effective population size (Hill, 1972).

Englert and Bell (1970) reported that developmental time exhibited a skewed, but unimodal distribution in the samples of + Purdue Foundation beetles used in their selection study, and that the skewness of distribution was enough to create a difference observed in selection differentials, which in part were responsible for the asymmetrical response to selection present in their study.

When the distribution curves for pupation time were plotted for the present study, striking differences were observed between the two strains. The + strain exhibited nonnormality in the form of a bimodal distribution curve, while the *ap* strain exhibited a curve with a slight skewness in favor of early pupation. That initial variation should exist between the parameter distributions for the two populations in question was not particularly surprising, however, in view of other reports on developmental time in *Tribolium*.

Sokal and Sonleitner (1968) in a study examining the effects of natural selection, reported bimodal distribution curves for developmental time in populations of differing genotypes. Similar results were also observed by Sokal and Fujii (1972). In both instances the strains being compared were from samples of the Purdue + Foundation stock and the Chicago Black Strain. More recently, Beckman (1975) reported the existence of bimodal distributions for two additional genetic strains, one possessing the "paddle" mutation, the other, "pearl".

Howe (1966) reported that regardless of the population of *T. castaneum* examined, i.e., natural or laboratory populations, whenever distribution frequencies of developmental time revealed bimodal distribution curves, they were due to the extreme genetic variation present in a "mixed" population. Dawson (1965) reported that natural selection would favor an intermediate optimum in developmental time, which would strongly suggest that a unimodal distribution be present. In a more recent study, Dawson (1975) reported that in natural populations of low density, fast development would be favored, but that under normal laboratory cultuing conditions, including high population densities, fast development would not be favored.

Englert and Bell (1970) reported that successful response to selection for early pupation was indeed indicative of the failure of natural selection to

favor fast development in their laboratory population. They further suggested that the rapid appearance of an asymmetrical response to selection might be the consequence of the contribution of a few major genes controlling pupation time with dominance existing for early pupation.

Indeed, the existence of bimodality observed in the present study might be the consequence of the segregation of a few major genes controlling early pupation within the + Foundation Stock. The absence of this segregation in the *ap* strain is likely due to the consequence of interaction between background genes and the environmental conditions under which this study was conducted, or a greater degree of homozygosity due to its maintenance as a closed population.

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NOTES ON THE BIOLOGY OF COSMOPEPLA BIMACULATA (HEMIPTERA:PENTATOMIDAE) IN SOUTHERN ILLINOIS

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ABSTRACT.--A study of the biology of Cosmopepla bimaculata (Thomas) was conducted in southern Illinois between May 1972 and November 1974 and included field observations and laboratory rearing. Adults usually began emerging from overwintering sites in early May. Copulating pairs were noted at this time, and again in late June. The seasonal occurrence of the various nymphal instars is discussed. C. bimaculata was reared on green beans under constant light and temperature conditions. The incubation period averaged 7.0 days. The average durations of the 5 subsequent stadia were 3.5, 10.1, 9.6, 12.5 and 18.9 days.

Field and laboratory investigations of Cosmopepla bimaculata (Thomas) were conducted between May 1972 and November 1974 in southern Illinois. All field data were collected in the La Rue-Pine Hills Ecological Area (hereafter referred to as Pine Hills), Union Co.

C. bimaculata occurs from Nova Scotia and New England south to Georgia, Texas and Mexico, and west to British Columbia and Washington (Blatchley 1926). It has been collected from numerous plant species including wild columbine (Van Duzee 1894), currant, mint, blackberry, raspberry, mullein, thistle (Kirkaldy 1909), moth mullein (Olsen 1910), Stachys, pokeberry (Hart 1919), wild carrot (Stoner 1920), snapdragon (Balduf 1926), greater ragweed, oats, nettle, bouncing-bet (Blatchley 1926), beardtongue (Griswold 1937), goldenrod (Torre-Bueno 1939), Collinsia verna Nuttall, Ranunculus abortivus L., Hydrophyllum appendiculatum Michaux (Esselbaugh 1948), and Gypsophila (Hoffman 1971). It has been reared from egg to adult (Olsen 1910, Esselbaugh 1948, McDonald 1968), brief notes have been published on its life history (Balduf 1926, McDonald 1968) including reproductive behavior (Fish and Alcock 1973), and the eggs (Esselbaugh 1946, McDonald 1968) and 1st-5th instars (DeCoursey and Esselbaugh 1962) have been described.

MATERIALS AND METHODS

Samples of the Pine Hills populations were taken 1-2 times per week during the 1972-74 seasons (ca. May-October) and sporadically during the remaining months. Specimens were collected by sweeping and hand-picking. Plants upon which individuals were feeding and/or copulating were recorded. Data from the 3 years were combined to allow a better understanding of the annual life cycle.

C. bimaculata was reared in the laboratory on green beans (Phaseolus vulgaris L.). Field-collected adults were maintained in 1-qt mason jars following the technique of McPherson (1971), and the resulting offspring reared following the technique of McPherson (1974) for Euschistus politus Uhler.

Food, filter paper and towelling were changed every 3-5 days. All specimens were kept in incubators maintained at 23.9 ± 0.6°C and constant light of ca. 130 ft-c.

RESULTS AND DISCUSSION

A total of 103 adults and 56 nymphs was collected during this study. Adults usually began to emerge from overwintering sites in early May although an exceptional specimen was swept from roadside vegetation on 12 March 1973. They were collected continuously until mid-September, but were most abundant early to mid-May (51 adults), and late June-early July (21 adults). Those collected during the 2nd peak were newly emerged, as evidenced by cast 5th instar skins. Copulating pairs were observed in early May and late June which corresponded with the 2 adult peaks.

No eggs were collected. Young instars (seventeen 1sts, six 2nds, six 3rds) were collected late May-mid-July, with no peaks of abundance discernable. Older instars (six 4ths, twenty one 5ths) were found mid-June-mid-September but were most abundant during the last 2 weeks of June (four 4ths, eleven 5ths) and the 3rd week of August (four 5ths). Based on laboratory developmental time, the 2nd peak probably resulted from eggs laid in June-July. This would correspond with the emergence of the 2nd peak of adults. However, it is possible these eggs were laid by some long-lived spring adults. Thus, C. bimaculata may have been bivoltine at Pine Hills but, because the 2nd peak of older nymphs was so small, it is possible that it was partially bivoltine, or even univoltine.

C. bimaculata was observed feeding on curly dock (Rumex crispus L.), buckhorn (Plantago lanceolata L.), wild carrot

(Daucus carota L.), cheat (Bromus secalinus L.), blue speedwell (Veronica arvensis L.), Carolina cranesbill (Geranium carolinianum L.), and wood-sage (Teucrium canadense L.), copulating on blue speedwell, trumpet-creeper [Campsis radicans (L.)], and common mullein (Verbascum thapsis L.). It was also collected from timothy (Phleum pratense L.).

Approximately 20 adults were collect on 5 May 1972 and placed in mason jars in the laboratory. Some were in copulo when captured. The ♀♀ laid 26 clusters, all on cheesecloth, totaling 201 eggs ($\bar{x}$ = 7.7, range = 1-20). Esselbaugh (1946) reported his specimens averaged ca. 11 eggs/cluster (range = 2-24), McDonald (1968), 11.5 ± 1.0 eggs. The incubation period averaged 7.0 days (Table 1).

Table 1.--Durations (days) of immature stages of Cosmopepla bimaculata reared in the laboratory. Compare these results with those reported by Esselbaugh 1948(1), Olsen 1910(2), and McDonald 1968(3).

Stage	No. individuals	Days Range	Days Avg.	Days Avg.(1)	Days Avg.(2)	Days Avg.(3)
Egg	171[a]	6-9	7.0	4.6	7.0	4.7
Nymph						
1st instar	170	3-5	3.5	2.7	4.0	3.2
2nd instar	133	7-19	10.1	8.3	6.0	4.7
3rd instar	108	5-16	9.6	6.8	5.0	4.2
4th instar	104	3-22	12.5	7.9	7.0	2.9
5th instar	96	9-26	18.9	10.3	9-13[b]	6.4

[a]201 eggs laid but 30 failed to hatch.
[b]no average given.

The 1st instars emerged through pseudopercula and clustered atop the egg shells for the entire stadium, unless disturbed. No feeding was observed during this stadium. The durations of the 1st, 2nd, 3rd, 4th, and 5th stadia averaged 3.5, 10.1, 9.6, 12.5 and 18.9 days, respectively (Table 1).

Durations of the various stadia in this experiment differed from those in the experiments of Esselbaugh (1948), Olsen (1910), and McDonald (1968) (Table 1). Esselbaugh reared his animals (collected in Urbana, Illinois) on lettuce in a room affected by outdoor temperatures. Olsen (1910) apparently collected his specimens on Long Island, New York, reared them on moth mullein (Verbascum blattaria L.), but gave no additional information on rearing conditions. McDonald (1968) reared his animals (collected in Alberta, Canada) on Stachys palustris L. at ca. the same temperature (eggs = 23.5°C, 1st-5th instars = 23.0°C) as mine but under a 14L:10D photoperiod. It is probable that the differences in rearing technique account for the differences in developmental time between the 4 sets of data. Perhaps, however, the progressive decrease in the 2nd-5th stadia from southern Illinois to Alberta, Canada, reflects the progressive decrease in length of active season. This possibility warrants further investigation.

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NURSERY POPULATIONS OF PIPISTRELLUS SUBFLAVUS (CHIROPTERA, VESPERTILIONIDAE) IN MISSOURI

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Abstract: Two cave roosts, microclimates, and population structure are described.

On 4 July 1975 we observed a nursery population of Pipistrellus subflavus near Sullivan, Crawford County, Missouri. The bats were in a 8 m high dome in the twilight zone of a cave, about 30 m from the entrance. The population was in a single, tight cluster and consisted of 7 adults and an estimated 14 small young. In late afternoon temperatures at the top of the dome were 22.0°C for rock surface and 23.0°C for ambient air (recorded with an Atkins telethermometer and banjo and shielded air probes).

On 9 July 1976 we observed a second nursery population of P. subflavus near Bonne Terre, St. Francois County, Missouri. The single cluster roosted in the dome of a cave room and contained 12 adults and 5 or more young. The room measured 5 m x 7 m with a ceiling height of 5 m and was located well beyond the twilight zone of the cave. Ambient temperature 1 m below the bats was 13.6°C, recorded with a Schultheis quick-reading mercury thermometer. Relative humidity was 94 percent, recorded with a Bendix Psychron psychrometer. In both caves the bats were alert but did not take flight while we were present.

The nature of nursery roosts of this bat is poorly known. The only other recorded site is under eaves of a barn (Cope, 1972). We thank D. J. Howell and M. LaVal for field assistance.

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INSTABILITY CHARACTERISTICS OF SOLID-STATE CARRIER WAVES IN MICROWAVE CIRCUITS

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ABSTRACT - The interaction of solid-state carrier waves with rf circuit waves is analyzed in order to predict the wave instabilities and to investigate the wave characteristics. A general dispersion relation for the coupled waves traveling along a finite semiconductor slab is developed by analyzing the interaction between the carrier waves and the rf waves. The effects of collision, diffusion, insulator thickness, semiconductor thickness and substrate material are included in the analysis. The instability characteristics in solids are obtained by solving the dispersion equation for the system. The results indicate the feasibility of net gain of the microwave signal in several N-type semiconductors. The experimental results are represented to confirm the general feature of the theoretical analysis. The maximum gain of 5.2 db was obtained through the coupled circuit.

Introduction

Several workers (Solymer, Ash, Sumi, and Hines 1966) have investigated the wave amplification due to the coupling between the space charge wave and the rf circuit wave in solid-state materials. In most cases, many important aspects of the analysis such as the boundary condition for wave interaction and the way of finding roots of the dispersion equation were not clearly justified. The reflected waves and surface charge on the semiconductor were usually neglected, in spite of the finite dimension and conductivity of the slab. The approaches were oversimplified and hence the results were either inacculate or doubtful.

The method of analysis reported thus far has been either an extension of Pierce's approach (Solymer and Ash 1966) or the transverse admittance matching technique (Sumi 1966). Here, a formal way of deriving the dispersion relation is presented. For a nontrivial solution of the fields in the slab, the determinant of the field matrix must vanish, which gives the dispersion relation. The device structure considered is shown in Fig. 1.

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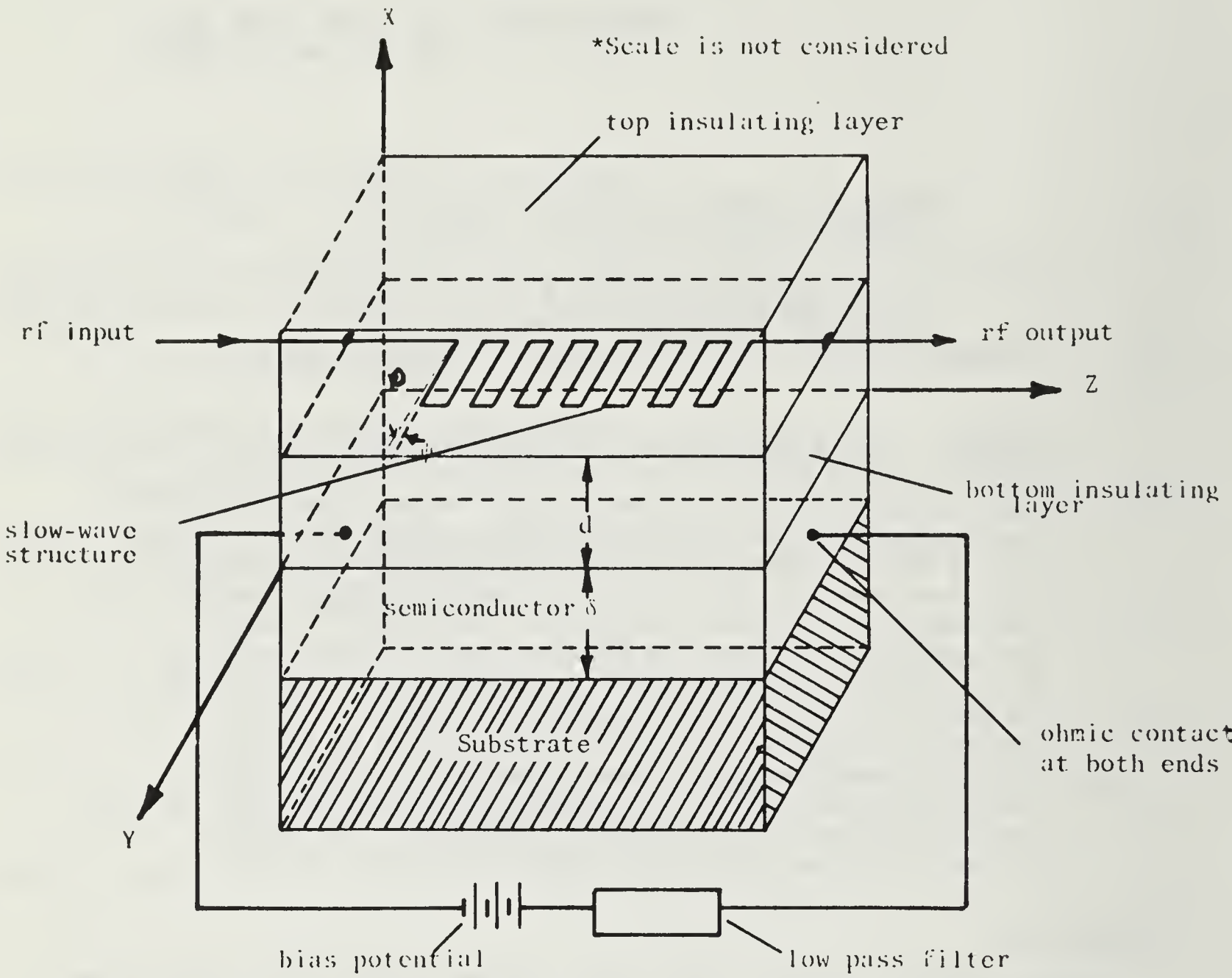
*Dr. Ho is professor of the Electrical Engineering Department at Michigan State University.



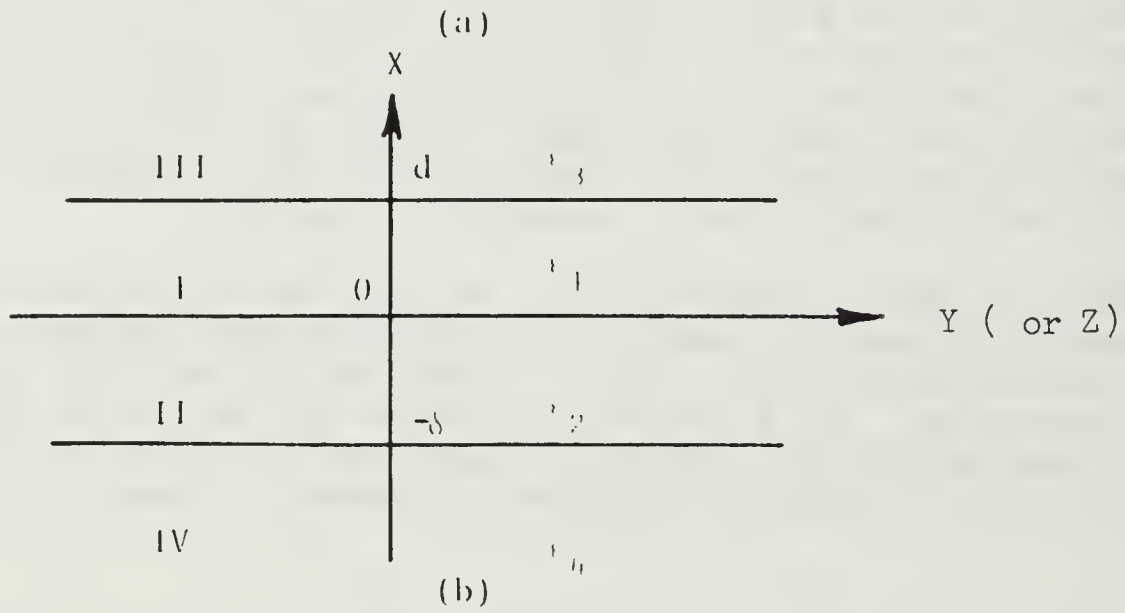


Fig. 1 One possible structure for solid-state traveling-wave amplifier. (a) Sketch showing coupling between space charge waves and external microwave fields (b) Schematic planar layout of (a).

Boundary Conditions

Based on the device configuration presented in Fig. 1, the following boundary conditions are observed: (1) The tangential electric field component is continuous at x=0, x=d and x=- δ. (2) The normal rf velocity vanishes at x=0 and x=- δ. (3) The tangential magnetic field component is continuous at x=0 and x=- δ since the conductivity of the semiconductor is finite. (4) Along the direction of the tape-line, the tangential electric field at the edge of the tape must vanish since the tape is considered to be a perfect conductor. (5) The component of the magnetic field tangent to the tape-line must be continuous since no current flows perpendicular to the tape. The second boundary condition is well-known in a gaseous plasma. Since the cloud of carriers has the nature of solid-state plasma, the normal rf component of carrier velocity must vanish at the boundaries. The last two conditions for the slow-wave circuit were used by Chu (Chu 1948).

Field Analysis in Solids

In the device operation, a d-c potential is applied across the semiconductor, such that the carrier stream will drift at a velocity of u_o in the z-direction. One type of charged carrier, namely electrons, will be considered for simplicity and $e^{j(\omega t-kz)}$ is assumed for the wave propagation. The first moment of the Boltzmann equation in Eulerian variables is

$$\left(\frac{\partial}{\partial t} + \vec{v} \cdot \nabla + \nu\right)\vec{v} = \frac{q}{m^*}\left(\vec{E} + \vec{v} \times \vec{B}\right) - \frac{v_t^2}{n}\nabla n$$

where n is carrier density, v_t is thermal velocity, m^* is effective mass of a carrier, and ν is total collion frequency. Since the gradient of the rf carrier density is $\nabla n_1 = -\frac{\varepsilon}{e^2}\nabla\nabla\cdot\vec{E}_1$ from the divergence equation of $\vec{E}$, the rf carrier velocity can be derived from the Boltzmann equation as

$$\vec{v}_1 = \frac{j\eta^*}{\omega_\nu}\left(\vec{E}_1 - \frac{v_t^2}{\omega_p^2}\nabla\nabla\cdot\vec{E}_1\right) \qquad (1)$$

where $\omega_\nu = \omega - ku_o - j\nu$, $\eta^* = |e|/m^*$, $v_t^2 = \gamma kT/m^*$, $\omega_p^2 = n_o e^2/em^*$

and ν is the collision frequency.

Using Maxwell's curl equations and Equation (1) the wave equation for electric field intensity $\vec{E}$ is

$$\nabla^2\vec{E}_1 + \omega^2\mu_o\varepsilon_2\left(1 - \frac{\omega_p^2}{\omega\omega_\nu}\right)\vec{E}_1 - j\omega\mu_o\varepsilon_2\vec{u}_o\nabla\cdot\vec{E} + \left(\frac{\omega\mu_o\varepsilon_2 v_t^2}{\omega_\nu} - 1\right)\cdot\nabla\nabla\cdot\vec{E}_1 = 0 \qquad (2)$$

For two-dimensional analysis, with $\frac{\partial}{\partial y} = 0$, the wave equation can be written in the following form:

$$\begin{bmatrix} \left(\frac{\partial^2}{\partial x^2} + jga^2\right) & 0 & k(g-j) \\ 0 & \left(\frac{\partial^2}{\partial x^2} - a^2\right) & 0 \\ jk\left(\frac{a^2}{k^2} + \frac{b^2}{jg}\right)\frac{\partial}{\partial x} & 0 & \left(\frac{\partial^2}{\partial x^2} - \frac{j\,b^2}{b}\right) \end{bmatrix} \begin{bmatrix} E_{1x} \\ E_{1y} \\ E_{1z} \end{bmatrix} = 0 \qquad (3)$$

where $a^2 = k^2 - \omega^2 \mu_0 \varepsilon_2 \left(1 - \omega_p^2 / \omega\omega_\nu\right)$, $b^2 = \omega_\nu / v_t^2 \cdot \left[-\omega + ku_o + \omega_p^2 + k^2 v_t^2\right) / \omega_\nu \Big]$

and $g = j\omega_\nu / (\omega \mu_0 \varepsilon_0 v_t^2)$.

It can be easily shown that, without the application of the longitudinal d-c magnetic field, the fields can be divided into independent TM and TE waves(Agdur 1958). From the two-dimensional assumption, the only magnetic field for the TM waves is H_{1y} while $H_{1x} = H_{1z} = 0$. By solving Equation (3) and using Maxwell's equations,we obtain the field solutions in the semiconductor region as follows:

TM Waves

$$E_{1z} = A_1 e^{ax} + A_2 e^{-ax} + A_3 e^{bx} + A_4 e^{-bx} \qquad (4)$$

$$E_{1x} = \frac{jk}{a}\left(A_1 e^{ax} - A_2 e^{-ax}\right) + \frac{jbk\,(1 - j\,1/q)}{a^2 - jb^2/g}\left(A_3 e^{bx} - A_4 e^{-bx}\right) \qquad (5)$$

$$H_{1y} = \frac{\varepsilon_2 c_2^2}{j\,\omega}\left[\frac{a^2 - k^2}{a}\left(A_1 e^{ax} - A_2 e^{-ax}\right) + \frac{(a^2 - k^2) - j\,1/g \cdot (b^2 - k^2)}{a^2 - j\,b^2/g}\, b\left(A_3 e^{bx} - A_4 e^{-bx}\right)\right] \qquad (6)$$

TE Waves

$$E_{1y} = B_1 e^{ax} + B_2 e^{-ax} \qquad (7)$$

$$H_{1x} = -\frac{k\varepsilon_2 c_2^2}{\omega}(B_1 e^{ax} + B_2 e^{-ax}) \tag{8}$$

$$H_{1z} = j\frac{\varepsilon_2 c_2^2 a}{\omega}(B_1 e^{ax} - B_2 e^{-ax}) \tag{9}$$

where $c_i^2 = 1/(\mu_0 \varepsilon_i)$ and A_1, A_2, A_3, A_4, B_1 and B_2 are all unknown coefficients to be determined from the boundary conditions. Note that A_2, A_4, B_2 cannot be neglected since the slab thickness is comparable to the skin depth and the reflected waves should be considered.

Electromagnetic Fields in Various Regions

The conduction current in the insulator region is zero, so the wave equation is reduced to the following simple form:

$$\frac{\partial^2 \vec{E}_1}{\partial x^2} - \gamma_i^2 \vec{E}_1 = 0 \tag{10}$$

where $\gamma_i^2 = k^2 - \omega^2/c_i^2$. Since the fields are attenuated in the $\pm x$-direction as given by the boundary conditions, therefore these fields have solutions of the form $e^{\pm \gamma i x}$, where i = 1,3, and 4 corresponding to regions I, III and IV respectively. Field solutions in all cases are tabulated in Table 1.

Dispersion Relation

Applying boundary conditions to all field solutions gives a 14 x 14 field coefficients matrix. A necessary and sufficient condition for a nontrivial solution is that the determinant of the field coefficient matrix shown in Table 2 be zero, which yields the following dispersion relation:

$$\frac{j\omega\varepsilon_4}{\gamma_4} \cdot \frac{(h_1+h_2/R)\cosh b\delta + R(h_1+h_2/R)(h_1+h_2/R+1)\sinh b\delta}{-8e^{-a\delta}+(h_1+h_2/R+2)\cosh b\delta + [R+1/R + R(h_1+h_2/R)]\sinh b\delta}$$

$$= \frac{j\omega\varepsilon_1}{\gamma_1} \cdot \frac{K_3(\Gamma_1+\tanh\gamma_1 d)-K_4(\Gamma_2-\tanh\gamma_1 d)}{-K_3(\Gamma_1+\tanh\gamma_1 d+1)+K_4(\Gamma_2\tanh\gamma_1 d-1)} \tag{11}$$

where: $K_3 = (1+e^{-2\gamma_1 d})\left[\frac{\gamma_1-a}{\gamma_1+a} - \frac{\gamma_4-a}{\gamma_4+a}e^{-2a\delta}\right]$,

TABLE 1

TABLE OF ELECTROMAGNETIC FIELD SOLUTIONS FOR ALL REGIONS

Region	Cases	TM Modes	TE Modes
$x \leq o$ Solid-state Region	General	$E_{1z} = A(e^{ax} + \eta e^{bx})e^{j(wt-kz)}$ $E_{1x} = \frac{jk}{a}A\left[e^{ax} + \frac{\eta ab(1-j\frac{1}{g})}{a^2-j\frac{b}{g}^2}e^{bx}\right]e^{j(wt-kz)}$ $H_{1y} = \frac{\epsilon_2 c_2^2}{jw}A\left[\frac{a^2-k^2}{a}e^{ax} + \eta\frac{(a^2-k^2)-j\frac{1}{g}(b^2-k^2)}{a^2-j\frac{b}{g}^2}e^{bx}\right]e^{j(wt-kz)}$	$E_{1y} = [Ce^{ax}]e^{j(wt-kz)}$ $H_{1x} = \left[-k\frac{c_2^2\epsilon_2}{w}Ce^{ax}\right]e^{j(wt-kz)}$ $H_{1z} = \left[j\frac{c_2^2\epsilon_2 a}{w}Ce^{ax}\right]e^{j(wt-kz)}$
	$\lvert w-ku_o\rvert < \nu$	$E_{1z} = A_1(e^{a_1x} + \eta_1 e^{b_1x})e^{j(wt-kz)}$ $E_{1x} = \frac{jk}{a_1}A_1\left[e^{a_1x} + \frac{\eta_1 a_1 b_1(1-j\frac{1}{g_1})}{a_1^2-j\frac{b_1}{g_1}^2}e^{b_1x}\right]e^{j(wt-kz)}$ $H_{1y} = \frac{j\epsilon_2 A_1}{a_1}\left[(w-j\frac{w_p^2}{\nu})e^{a_1x} - \frac{jku_o w_p^2}{\nu(w-ku_o-j\beta_2^2 D)}e^{b_1x}\right]e^{j(wt-kz)}$	$E_{1y} = \left[C_1e^{a_1x}\right]e^{j(wt-kz)}$ $H_{1x} = \left[-k\frac{c_2^2\epsilon_2}{w}C_1e^{a_1x}\right]e^{j(wt-kz)}$ $H_{1z} = \left[\frac{jc_2^2\epsilon_2 a_1}{w}C_1e^{a_1x}\right]e^{j(wt-kz)}$
	Collisionless ($\nu=o$)	$E_{1z} = \left[A_2e^{a_2x}\right]e^{j(wt-kz)}$ $E_{1x} = \left[\frac{jk}{a_2}A_2e^{a_2x}\right]e^{j(wt-kz)}$ $H_{1y} = \left[\frac{jw\epsilon_2}{a_2}A_2\left(1-\frac{w_p^2}{w(w-ku_o)}\right)e^{a_2x}\right]e^{j(wt-kz)}$	$E_{1y} = \left[C_2e^{a_2x}\right]e^{j(wt-kz)}$ $H_{1x} = \left[-k\frac{c_2^2\epsilon_2}{w}C_2e^{a_2x}\right]e^{j(wt-kz)}$ $H_{1z} = \left[\frac{jc_2^2\epsilon_2 a_2}{w}C_2e^{a_2x}\right]e^{j(wt-kz)}$
$o \leq x \leq d$ Circuit Region	General	$E_{1z} = \left[F_2e^{-\gamma_1x} + F_3e^{\gamma_1x}\right]e^{j(wt-kz)}$ $E_{1x} = \left[-\frac{jk}{\gamma_1}(F_2e^{-\gamma_1x} - F_3e^{\gamma_1x})\right]e^{j(wt-kz)}$ $H_{1y} = \left[-\frac{jw\epsilon_1}{\gamma_1}(F_2e^{-\gamma_1x} - F_3e^{\gamma_1x})\right]e^{j(wt-kz)}$	$E_{1y} = \left[G_2e^{-\gamma_1x} + G_3e^{\gamma_1x}\right]e^{j(wt-kz)}$ $H_{1x} = \left[-\frac{w\epsilon_1}{\beta_1^2}(G_2e^{-\gamma_1x} - G_3e^{\gamma_1x})\right]e^{j(wt-kz)}$ $H_{1z} = \left[-\frac{jw\epsilon_1\gamma_1}{\beta_1^2}(G_2e^{-\gamma_1x} - G_3e^{\gamma_1x})\right]e^{j(wt-kz)}$
$x \geq d$ Circuit Region	General	$E_{1z} = \left[F_1e^{-\gamma_3x}\right]e^{j(wt-kz)}$ $E_{1x} = \left[-\frac{jk}{\gamma_3}F_1e^{-\gamma_3x}\right]e^{j(wt-kz)}$ $H_{1y} = \left[-\frac{jw\epsilon_3}{\gamma_3}F_1e^{-\gamma_3x}\right]e^{j(wt-kz)}$	$E_{1y} = \left[G_1e^{-\gamma_3x}\right]e^{j(wt-kz)}$ $H_{1x} = \left[-\frac{w\epsilon_3 k}{\beta_3^2}G_1e^{-\gamma_1x}\right]e^{j(wt-kz)}$ $H_{1z} = \left[-\frac{jw\epsilon_3\gamma_3}{\beta_3^2}G_1e^{-\gamma_3x}\right]e^{j(wt-kz)}$

$$
\begin{bmatrix}
1 & -1 & -R & R & & & & & & & & & & & & & & & & \\
e^{-a\delta} & -e^{a\delta} & -e^{-b\delta}R & e^{b\delta}R & & & & & & & & & & & & & & & & \\
e^{-a\delta} & e^{a\delta} & e^{-b\delta} & e^{b\delta} & & & & & & & -e^{-\gamma_4\delta} & & & & & & & & & \\
h_1e^{-a\delta} & h_1e^{a\delta} & h_2e^{-b\delta} & h_2e^{b\delta} & & & & & & & -e^{-\gamma_4\delta} & & & & & & & & & \\
 & & & & e^{-a\delta} & e^{a\delta} & & & & & & & & & & & -e^{-\gamma_4\delta} & & & \\
 & & & & e^{-a\delta} & -e^{a\delta} & & & & & & & & & & & -\frac{\gamma_4}{a}e^{-\gamma_4\delta} & & & \\
1 & 1 & 1 & 1 & & & & & -1 & -1 & & & & & & & & & & \\
 & & & & 1 & 1 & & & & & & & & & -1 & -1 & & & & \\
\Delta_o h_1 & \Delta_o h_1 & \Delta_o h_2 & \Delta_o h_2 & & & & & -1 & 1 & & & & & & & & & & \\
 & & & & 1 & -1 & & & & & & & & & \frac{\delta_1}{a} & -\frac{\delta_1}{a} & & & & \\
 & & & & & & -e^{-\gamma_3 d} & e^{-\gamma_1 d} & e^{\gamma_1 d} & & & & & & & & & & & \\
 & & & & & & & & & & -e^{-\delta_3 d} & e^{-\gamma_1 d} & e^{\gamma_1 d} & & & & & & & \\
 & & & & & & \tan\psi & & & & 1 & & & & & & & & & \\
 & & & & & & -\Delta_2 e^{(\gamma_1-\gamma_3)} & 1 & -e^{2\gamma_1 d} & & -\Delta_3 e^{(\gamma_1-\gamma_3)d} & \Delta_1 & \Delta_1 e^{2\gamma_1 d} & & & & & & & \\
\end{bmatrix}
$$

where $\Delta_o = -\frac{\varepsilon_4\gamma_1}{\varepsilon_1\gamma_4}$, $\Delta_1 = (\frac{c_1\gamma_1}{\omega})^2 \tan\psi$, $\Delta_2 = \frac{\varepsilon_3\gamma_1}{\varepsilon_1\gamma_3}$, $\Delta_3 = (\frac{c_3}{\omega})^2(\frac{\varepsilon_3}{\varepsilon_1})\gamma_1\gamma_3 \tan\psi$

TABLE 2

ELECTROMAGNETIC FIELD COEFFICIENT MATRIX

$$K_4 = (1+e^{2\gamma_1 d}) \left[1 - \frac{(\gamma_4-a)(\gamma_1-a)}{(\gamma_4+a)(\gamma_1+a)} e^{-2a\delta} \right] ,$$

$$\Gamma_{\substack{1\\2}} = \gamma_1 \left(\frac{\gamma_1}{\beta_{s_1}^2} \mp \frac{\varepsilon_3 \gamma_3}{\beta_{s_3} \varepsilon_1} \pm \frac{\varepsilon_3}{\varepsilon \gamma_3} \right) ,$$

$$\beta_{s_1} = \frac{\omega}{c_1 \tan\Psi} , \quad \beta_{s_3} = \frac{\omega}{c_3 \tan\Psi} , \quad h_1 = \left(\frac{\varepsilon_2}{\varepsilon_4}\right)\left(\frac{\gamma_4}{a}\right)\left(\frac{c_2}{\omega}\right)(k^2-a^2) ,$$

$$h_2 = \left(\frac{\varepsilon_2}{\varepsilon_4}\right)\left(\gamma_4 b\right)\left(\frac{c_2}{\omega}\right)^2 \frac{g(k^2-a^2) + j(b^2-k^2)}{ga^2-jb^2}$$

$$R = ab \frac{j-g}{ga^2-jb^2} - \frac{v_t^2}{\omega_p} \frac{b^2(j-g)}{ga^2-jb^2} + 1$$

and Ψ is the angle between the tape and the y-axis.

As one can see from Equation (11), the equation is too complicated with complex coefficients to obtain the device gain in an explicit analytical form. Hence, numerical analysis has been performed for materials such as N-type Si, Ge, GaAs, and InSb. The results of this calculations are presented in Fig. 2, Fig. 3, and Fig. 4.

Result and Discussion

A formal and straightforward way of obtaining the dispersion relation of a semiconductor slab has been presented. The results are in agreement with the conventional transverse matching technique (Sumi 1966) in general but are more accurate. From the computer solution, InSb is the most promising material, as was predicted by Sumi (Sumi 1966), because InSb possesses the highest drift velocity of most semiconductor materials.

The phase constant of the device is plotted in Fig. 2. Fig. 2 shows that the microwave signal can be amplified only if the phase constant of the coupled system is close to ω/u_0 where ω is operating frequency or $(2\pi f)$ and u_0 is dc carrier velocity. It is interesting to note that the amplification occurs when the phase velocity of the coupled system is synchronous with the carrier drift velocity which is identical to the theory of traveling-wave amplifier tube. In the frequency range of 1-10 GHz, attenuation curves of the $n=10^{14}/cm^3$ materials are presented in Fig. 3. All material constants for computation are tabulated in Table 3. It should be noted that the device gain

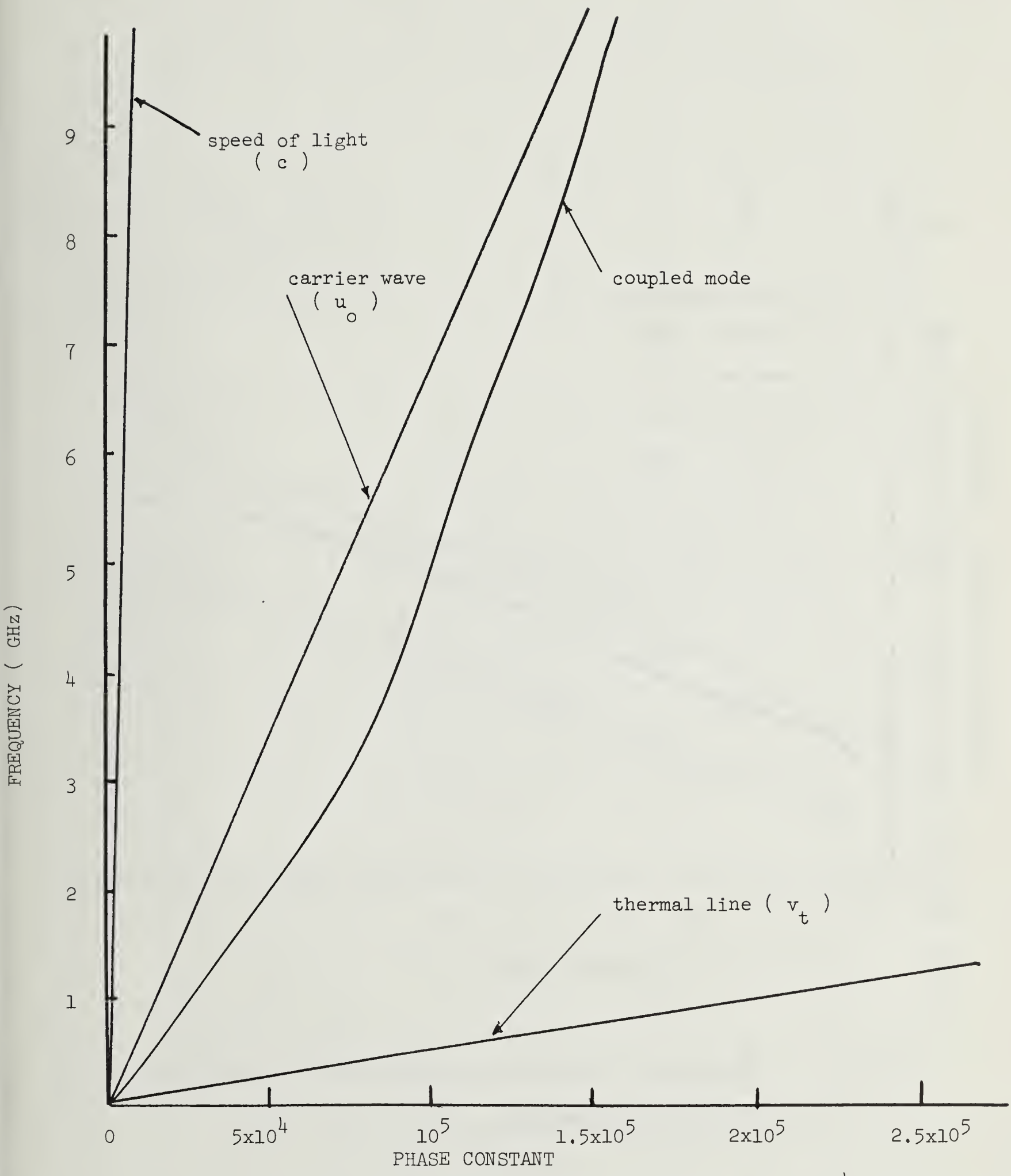


Fig. 2 Frequency vs. phase constant diagram for a $n = 10^{14}$ InSb sample.

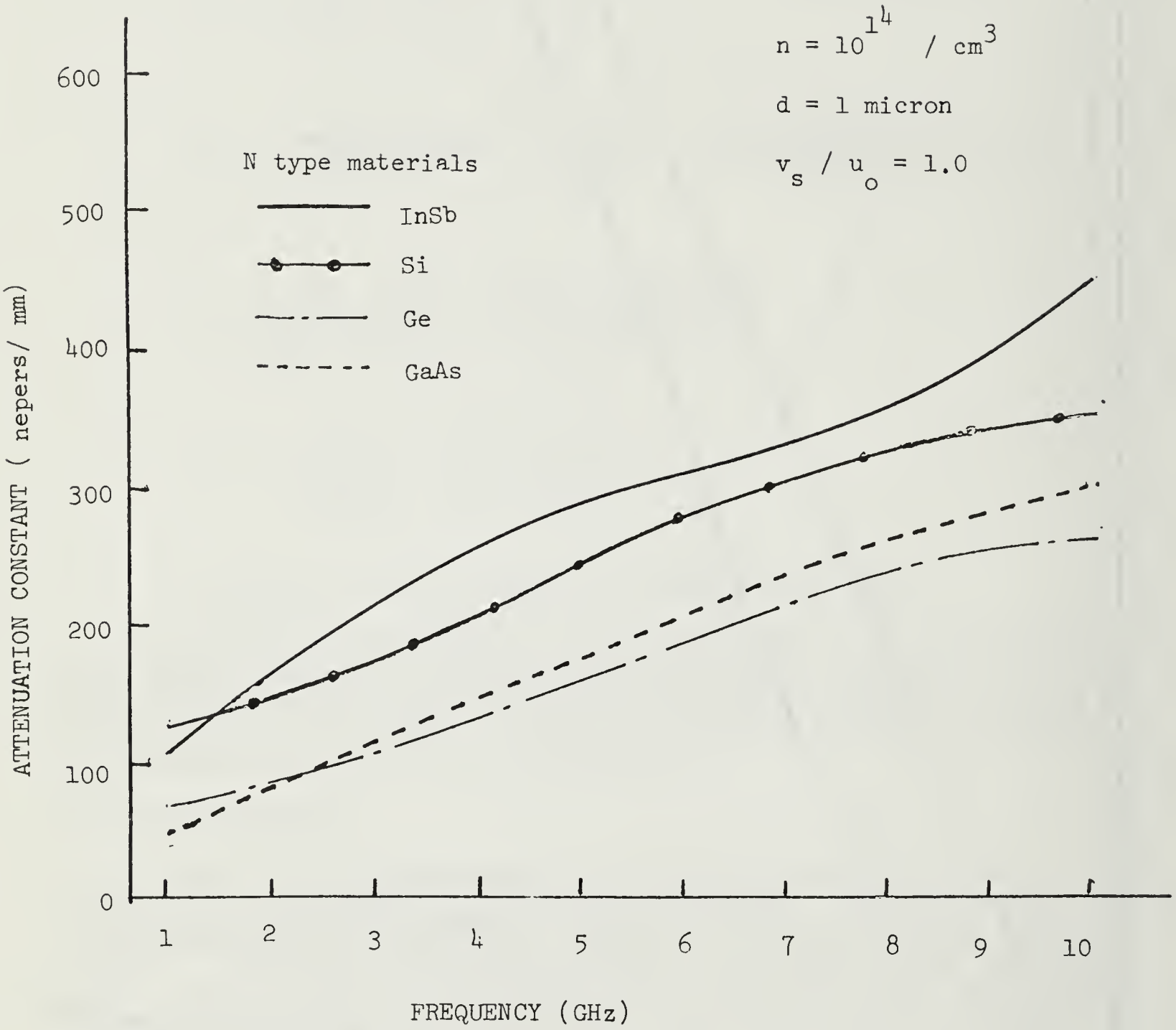


Fig. 3 Variation of attenuation constant with frequency for four different materials.

Material	Energy gap E_g(eV)	Rel. perm. ε_r	m^*/m_e	Mobility (cm^2/v_s)	Resitivity (Ω-cm)	Drift velocity u_0(cm/sec)	Density ($/cm^3$)
Si	1.11	11.8	0.33	$1.2x10^3$	45	$1x10^6$-$2x10^7$	10^{14}
Ge	0.67	16.0	0.04	$3.8x10^3$	60	$6x10^6$-$1x10^7$	10^{14}
				$3.6x10^3$	5		10^{15}
GaAs	1.53	12.5	0.072	$7.4.x10^3$	44.2	$6x10^6$-$1x10^7$	10^{13}
				$5.8x10^3$	9.68		10^{14}
				$5.5x10^3$	2.50		10^{15}
InSb	0.18	15.7	0.016	$3.15x10^5$	0.50	$6x10^7$-$9x10^7$	10^{13}
				$5.45x10^5$	0.031		10^{14}
				$4.0x10^5$	0.013		10^{15}

TABLE 3

TYPICAL NUMERICAL VALUES FOR SEVERAL SEMICONDUCTOR MATERIALS

increases as the operating frequency increases since in the program the active device length has been assumed to be identical for all frequencies. The actual gain can be easily figured out for an operating frequency, from the figure. Therefore, the actual gain appears decreasing for higher frequencies. However, this device has some merit for the amplification of microwave and millimeter wave signals, compared to most of microwave active device because it has an excellent noise figure and high frequency response, although the electron beam device has no competition for high power operation.

From the dispersion relation, computer solution shows that optimum gain of the device is a strong function of insulating layer thickness, circuit velocity, collision frequency and carrier drift velocity. The insulating layer impairs operation drastically as can be seen in Fig. 4, because electromagnetic field of the tape-line decreases rapidly in the transverse direction. The net gain decreases as the circuit velocity increases, which is expected since the circuit wave and the carrier wave can not be synchronized after then. The result also confirms Vural's suggestion that the collision will only lead to reduction of amplification (Vural and Bloom 1967).

Several experimental devices have been built and tested. One such device is displayed in Fig. 5. The chosen semiconductor for the device is highly doped N-type material as shown in Table3 . To make the capacitively-coupled meander circuit, the dielectric material KMER by Kodak was deposited on the first type of fingers. The thickness of the dielectric layer is a half to one micron while the slab thickness is 3 to 5 microns. One side of circuit pattern is shown in Fig. 5a and the small portion of the complete circuit is taken by the enlargement of a microscope as shown in Fig. 5b. The final test structure is presented in Fig. 5c. Fig. 6 presents relative power level of rf transmitted waves from the device. A maximum power gain for Si-layer, as high as 5.2 db, was observed from Fig. 6. However, the gain variation of the device with frequency is extremely sharp because of large terminal and transmission mismatches.

The device built with the InSb material has not been as successful as predicted from the theoretical analysis, because the etching technique for the InSb has not been well developed yet. The usefulness of this type of device will heavily depend upon proper design and fabrication. If these can be improved by the advanced thin film technology, this device should be most desirable for space communication, considering its weight and low power operation. Further work in fabricating comparatively perfect meander circuit may be developed with electron-beam scanning techniques. This method will reduce the tape size in length and then increase the optimum operating frequencies up to 40 GHz.

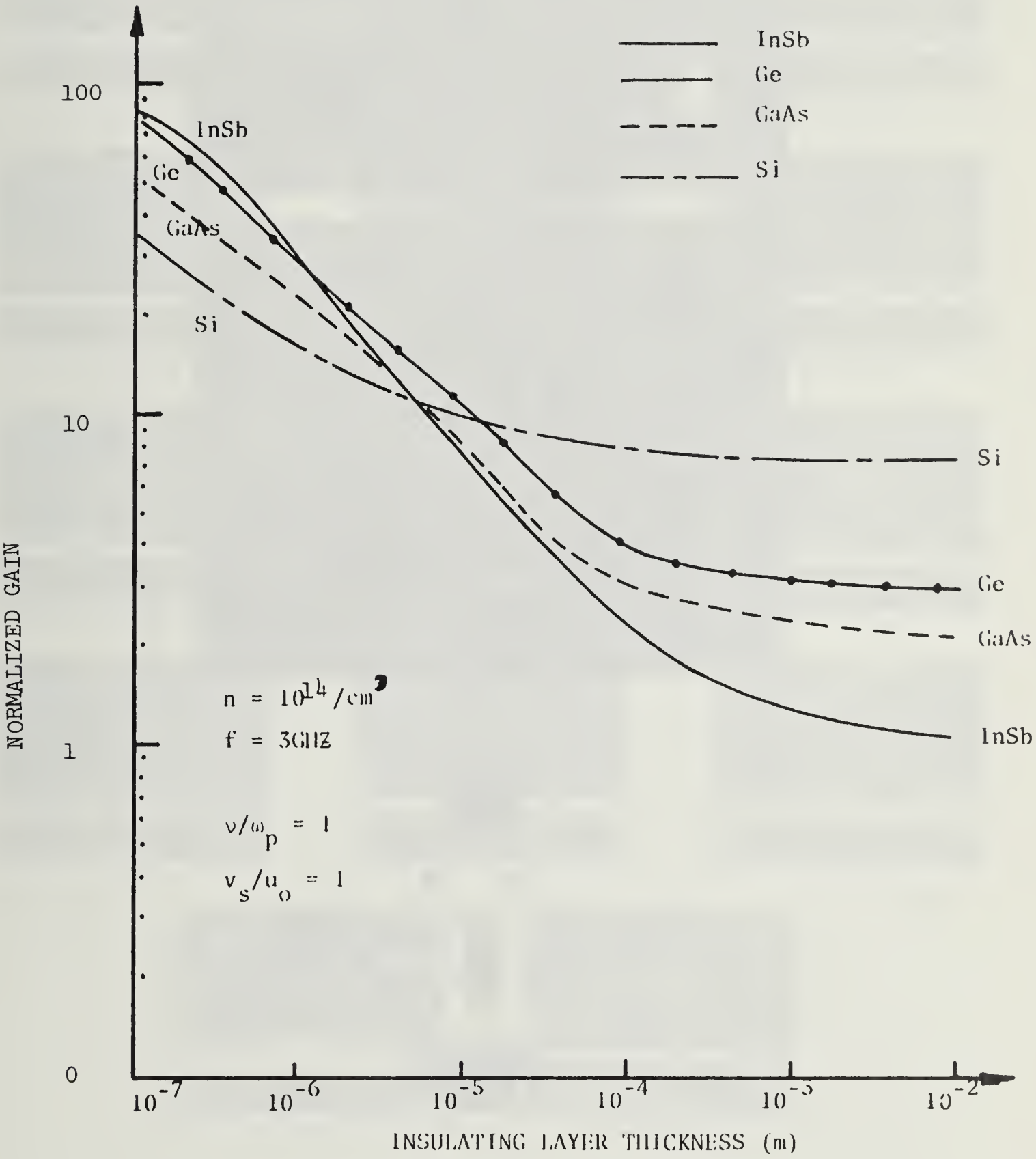


Fig. 4. Gain characteristics for various values of an insulating layer thickness (d)

(a)

(b)

(c)

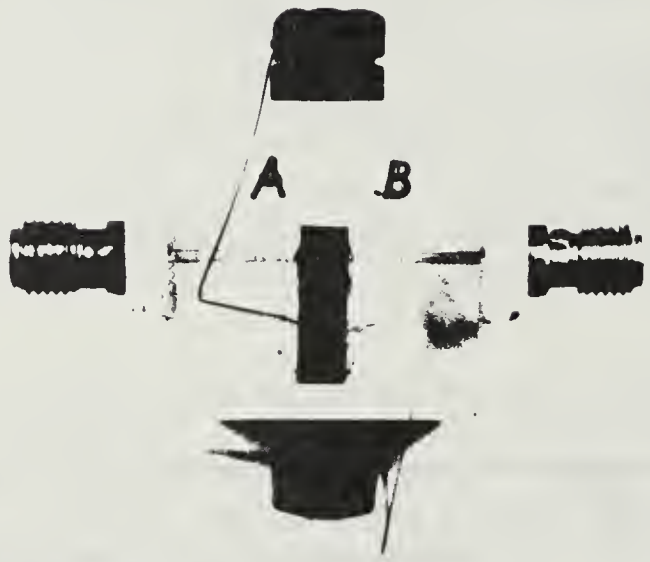
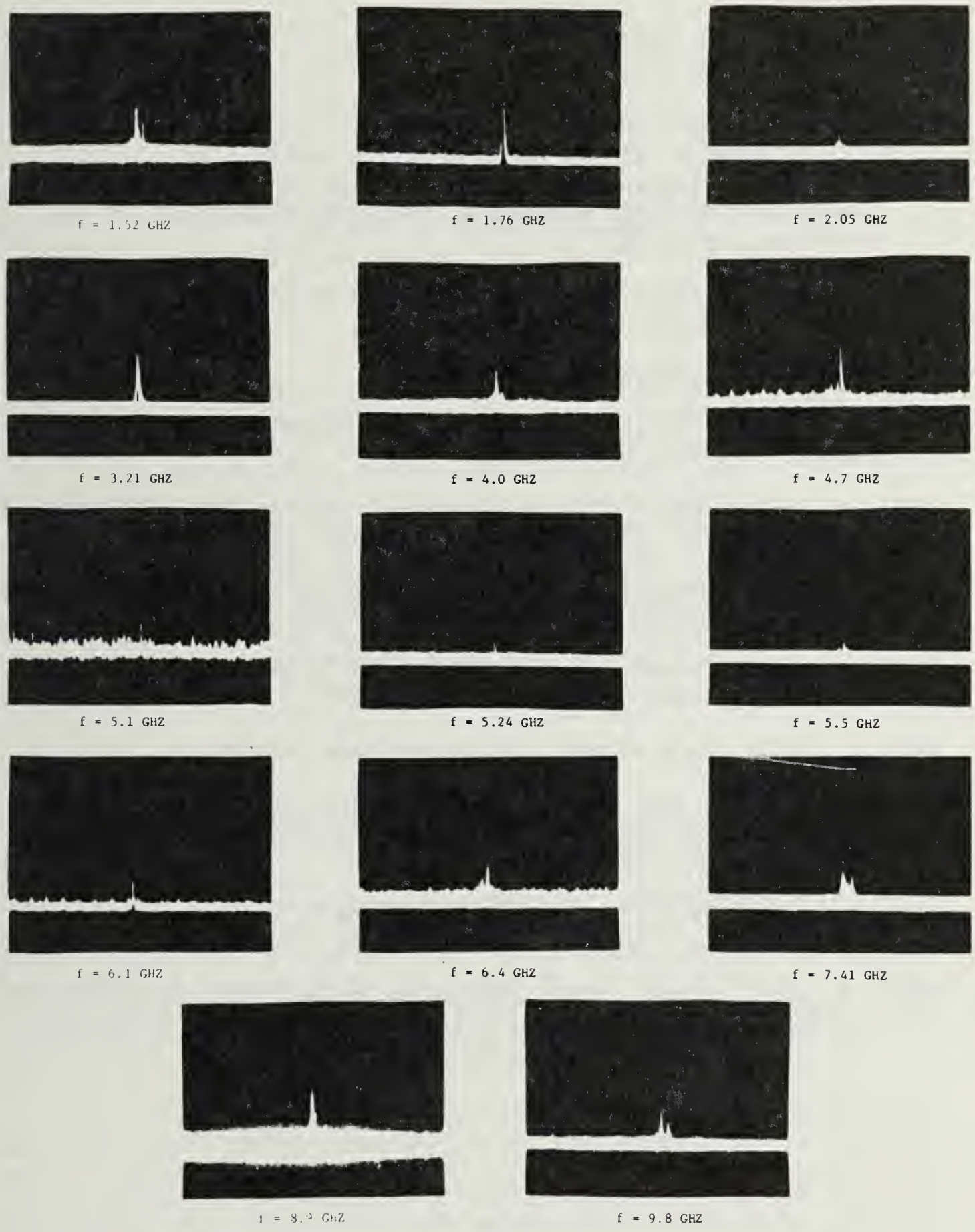


Fig. 5 Slow-wave circuit and test structure of a solid-state traveling-wave amplifier. (a) One side of the meander circuit. (b) A small portion of the complete circuit after fabrication. (c) A final assembly of the test structure.



Relative power level of r.f. transmitted waves for several different frequencies. Increment is 1 dB as power drop.

Fig. 6

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ACUTE TOXICITY OF RESIDUAL CHLORINE ON BLUEGILL AND CHANNEL CATFISH IN ILLINOIS

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ABSTRACT

Ninety-six hour residual chlorine bioassays were conducted on bluegill and channel catfish with a modified Mount and Brungs proportional dilutor. The 96-hour TL_{50}s for bluegill and catfish were 0.33 and 0.09 mg/l, respectively, and the environmental effects of water temperature and fish weight were quantified through linear regression analyses. The product of the 96-hour TL_{50} and the 0.1 Illinois safety factor places the allowable residual chlorine at the limit of detection for the amperometric titrator and essentially means no detectable residual chlorine is allowed in Illinois waters.

INTRODUCTION

The proper management and surveillance of water quality is predicated on the need to maintain suitable quality for each use that is made or will be made of Illinois' lakes and streams. Thus it is necessary to know the water quality criteria for each use, if effective rules are to be applied to sources of waste discharging into the water bodies of Illinois. Water quality criteria for potable water, recreation, agriculture, and industrial use are fairly well defined. On the other hand, there remains considerable doubt on the water quality standards required to sustain an adequate fishery. This is particularly true with regard to heavy metals, ammonia, residual chlorine, and organochemicals.

The current regulations in Illinois, where numerical values have been developed limiting presumably toxic substances in waste discharges and natural water bodies, are based upon studies using, as test specimens, aquatic organisms not native to Illinois waters. In addition to a list of chemical constituents for which maximum permissible concentrations have been determined, Rule 203(h) of the Water Pollution Regulations of Illinois states:

> Any substance toxic to aquatic life shall not exceed one-tenth of the 48-hour median tolerance limit (48-hr TLm) for native fish or essential fish food organisms.

It is within the purview of this rule that this investigation regarding the effects of residual chlorine upon some native fishes of Illinois was undertaken.

Since the adoption of the rule, changes of the 48-hr TLm to 96-hr TLm have been considered and will most likely be made. Here the median tolerance limit (TLm) is the concentration at which 50% of the test specimens survive. It is also referred to as LC_{50} (lethal concentration) and TL_{50}.

RESIDUAL CHLORINE

The Illinois Environmental Protection Agency has established a limit of 400 fecal coliform per 100 ml in all effluents. This requires disinfection procedures; and the most common disinfection practice in Illinois is chlorination.

When chlorine is introduced into water either in gaseous form (Cl_2) or as hypochlorite ($Ca(OCl)_2$), the same end products are produced. These are hypochlorous acid (HOCl) and the hypochlorite ion (OCl^-). Chlorine, hypochlorous acid, and hypochlorite ions in water are considered free residual chlorine. If ammonia is present, its reaction with chlorine and hypochlorous acid produces chloramines. Chloramines in water are referred to as combined residual chlorine. The total residual chlorine in water is the sum of the free and combined residual chlorine. Residual chlorine is primarily introduced into the aquatic environment from the disinfection of sewage plant effluents. The other major source of residual chlorine is cooling water discharges from electrical generating plants where chlorine is frequently used for minimizing the fouling of heat transfer surfaces. For Illinois conditions, the exposure of fish to residual chlorine is more likely in the case of waste effluents than in the case of cooling water discharges.

In the reaction of chlorine or hypochlorous acid with ammonia, three chloramines may be produced. They include monochloramine (NH_2Cl), dichloramine ($NHCl_2$), and trichloramine (NCl_3). The relative amounts of each are dependent upon the molar ratio of chlorine to ammonia, pH, temperature, and length of reaction time. Monochloramine is the predominant form developed in treated sewage effluents during chlorination. It is the chloramine likely to occur in Illinois surface waters.

LITERATURE REVIEW

Rosenberger (1971) and Merkens (1958) concluded that free chlorine is slightly more toxic to fish than dichloramine and that dichloramine is more toxic than monochloramine. Thus total residual chlorine will be more toxic at pH values below 7 because the proportion of free chlorine and dichloramine is greater. Brungs (1973) states that the toxicity of

the principal components of total residual chlorine is not sufficiently different as to preclude using total residual chlorine to define acute toxicity.

Rosenberger (1971) used regression analysis in finding that larger fish died faster than smaller fish. He attributed this to a smaller ratio of gill surface area to body weight for larger fish. He assumed the gill to be the principal site of chlorine toxicity; however, Fobes (1971) found that the respiration rate of gill tissues from white suckers, exposed to lethal concentrations of chlorine, did not change. Dandy (1969) found "in all cases where the fish were exposed to chlorine until the first signs of disequilibrium occurred, and then immediately transferred to fresh water, death invariably ensued even though life expectancy in the chlorine solution at the time of transfer was several hours."

In standard laboratory bioassays, intolerant cold water fish, especially salmon and trout species, have been very sensitive to residual chlorine. Seven-day TL_{50}s of 0.01 to 0.08 mg/1 total residual chlorine have been reported (Merkens, 1958; Arthur, 1971; and Holland et al., 1960). For warm water fish, there is a narrow range of acute lethal chlorine concentrations. According to Arthur and Eaton (1971), all fathead minnows died within 72 hrs at 0.154 mg/1 but none died for 7 days at 0.085 mg/1.

Coventry (1935) stated that 0.4 mg/1 was lethal to sunfish and some bullheads. The 96-hr TL_{50} for black bullhead is 0.099 mg/1 according to Arthur (1971). A 15-hr TL_{50} for smallmouth bass was reported to be 0.5 mg/1 by Pyle (1960). Ninety-six hr TL_{50} values for largemouth bass, yellow perch, and white sucker are, respectively, 0.261, 0.205, and 0.132 mg/1 residual chlorine as reported by Arthur (1971).

The on-site testing of chlorine toxicity in sewage plant effluents by Basch et al. (1971) found 50% of rainbow trout dying in 96 hours at residual chlorine concentrations of 0.014 to 0.029 mg/1. When the effluents were not chlorinated, mortality did not occur.

In Maryland, northern Virginia, and southeastern Pennsylvania, Tsai (1968, 1970, and 1971) found that fish populations in small streams below 156 sewage treatment plants decreased in number of species toward more pollution-tolerant fish. The species diversity index was reduced 50% at 0.10 mg/1 residual chlorine. Fish were not found in water with a total residual chlorine of 0.37 mg/1.

Dickson et al. (1974) found that ammonia concentrations in the Clinch River, Virginia, had reduced most of the free chlorine to residual chlorine about 23 feet below the powerhouse discharge and that much of the residual chlorine was reduced in the first 500 feet. No bluegill mortality could be attributed to chlorine toxicity at any station, although a maximum of 0.55 mg/1 residual chlorine and 0.07 mg/1 of free chlorine was attained at one station.

METHODS AND EQUIPMENT

A modification of a proportional dilutor by Mount and Brungs (1967) was used whereby continuous water flow was provided through 12 glass test chambers. Each chamber has a volume of 22 liters, and the flow rate, 250 ml/min, produces a 95% volume displacement every 9 hours. The apparatus permits the continuous flow of 5 different concentrations of toxicant into duplicative test chambers with 2 chambers being available for control purposes.

Dilution water originates from municipal wells. Although residual chlorine has not been detected in the water, an activated charcoal filter has been installed on the main supply line prior to the introduction of water to the header boxes serving the dilutor.

Two header boxes are used. The first one, consisting of a fiberglassed steel barrel, permits regulation of water temperature. In it is a thermoregulator which can be set at a desired temperature. Significant cooling from the preset water temperature energizes a relay which activates a solenoid-controlled valve on a hot water line. Water flows from the steel barrel to a polyethylene plastic header box where air agitation keeps the contents mixed and provides a sustained dissolved oxygen level.

Stock solutions of residual chlorine were formulated by mixing 0.375 molar solutions of ammonia (from NH_4Cl ACS reagent grade) and HOCl (from 70% $Ca(OCl)_2$ technical grade) after adjustment to pH 8.4. The pH of the hypochlorous acid solution was adjusted with HCl; the pH of the ammonia solution was adjusted by the addition of NH_4OH, so that excess ammonia was present. By adding the HOCl solution slowly to the ammonia solution, the ratio of NH_3 to HOCl was always greater than one and thus insured the formation of monochloramine alone at pH 8.4 (Palin, 1950; Morris, 1975; and White, 1972). This form of residual chlorine is stable in the laboratory and environment and is the form most often found in natural waters. It is also the only form of residual chlorine found in the test chambers under conditions of analysis described by Wallace and Tiernan, Inc. (1971) and Johnson (1975). All forms of residual chlorine are quantified in terms of chlorine equivalent weights.

Hardness, alkalinity, and pH were determined in the control chambers and two other test chambers twice a day. Dissolved oxygen levels were measured at 0, 48, and 96 hrs, and water temperature was monitored continuously. Hardness determinations were by EDTA titrametric method with Eriochrome Black T as an indicator. Alkalinity and pH were determined by a Leeds and Northrup meter, using 0.02N H_2SO_4 as a titrant for alkalinity. Dissolved oxygen concentrations were measured by a Yellow Springs Instrument Model 54 oxygen meter; and temperature was monitored by a Yellow Springs Instrument Model 46 Tele-Thermometer with output recorded on a Cole-Parmer Mark VII recorder. Illumination for the 16-hr photoperiod was furnished by a combination of Duro-Test and Wide Spectrum Gro-lux fluorescent lighting in circuit with a timer.

The major modification in the dilutor apparatus was a syringe style pipettor with a two-way check valve from Manostat, which was fed from a container of toxicant. A normally open four-way Skinner air solenoid valve was placed into the circuit of the electrical switch, which operates the water solenoid valve in the standard Mount and Brungs dilutor. During cycling of the dilutor, the water bucket arm descends to engage the switch and breaks the electrical circuit. This shuts off the water solenoid valve and opens the air solenoid valve causing the arm of the air cylinder to be extended. The extended arm depresses the plunger of the pipettor to inject an exact amount of toxicant from the syringe into the mixing bowl. When the bucket arm rises to complete the electrical circuit again, the water solenoid valve opens and the air solenoid valve causes the air cylinder arm to retract. Two external springs return the plunger of the syringe to the locked position of the pipettor necessary for the intake of desired syringe volume through the two-way check valve. The original internal spring was replaced by two external springs to ensure the reliability necessary for the very frequent and long term cycling in bioassays. The advantages of this system are an easily adjustable volume of toxicant, a fail-safe design directly timed by dilutor function, an ability to dispense solutions with suspended particles as in the residual chlorine solution, and a relatively low price for a system comprised of an air solenoid valve, air cylinder, and pipettor.

Other than those chemical constituents periodically monitored, as mentioned earlier, the following characterize the water used in each bioassay run:

Chemical Oxygen Demand	ND	Fluoride	1.1 mg/l
Ammonia-N	0.08 mg/l	Silica	31.8 mg/l
Nitrate-N	5.18 mg/l	Calcium	123 mg/l
Phosphate-P	0.02 mg/l	Magnesium	42 mg/l
Sulfate	168 mg/l	Iron	0.03 mg/l
Chloride	34 mg/l	Mercury	$<2 \times 10^{-5}$ mg/l

CHARACTERISTICS AND REACTIONS OF FISHES

The bluegill (Lepomis macrochirus) used in this investigation were native fish removed from an area pond and separated into three weight groups. The channel catfish (Ictalurus punctatus) were obtained from the Illinois Department of Conservation after shipment from a hatchery in Senecaville, Ohio. In all instances, both bluegill and channel catfish were conditioned to the dilution water for a minimum of 10 days. When necessary, the temperature was raised 1°C/day and maintained at the desired temperature for 10 days.

At the beginning of each bioassay, the temperature and toxicant concentration for each test chamber were determined. One fish at a time was randomly placed in the different aquaria until each of the twelve chambers held 10 fish. Therefore each bioassay used 120 fish, including 20 control fish, giving a total of 600 bluegill and 280 channel catfish for the entire study.

Because of the rapid mortality at high concentrations, each bioassay was continuously monitored the first 32 hours. The time of each mortality could then be recorded. After death, the fish were thoroughly blotted to remove excess moisture, their lengths were measured, and they were weighed.

At the higher concentrations, the bluegill exhibited erratic swimming within 2 hours. From a resting position, the fish made a short, rapid movement forward, rested, then swam rapidly forward again. When the fish were near the bottom of the tank, they would dart upward, in a straight, diagonal line. This short, erratic swimming might occur 5 to 10 times in an hour.

As the bluegill's equilibrium was lost, it hovered near the surface, attempting to remain upright by using the caudal fin. Prodding produced a weak, lateral movement, completely different from the rapid, short, and straight swimming noted earlier. At this stage, removal of the bluegill from the toxicant concentration did not revive it.

Before death occurred, the fish rested ventral-side up on the bottom of the tank. Respiration was slow and erratic, with gill pouches spread open. Some fish had hemorrhaged pectoral and caudal fins. Death was determined by lack of reaction to prodding and the cessation of gill movement.

The stress patterns of the catfish and bluegill differed. The catfish were more listless, had increased ventilation rates and muscle contractions, and produced a mucous film on the body. They also became rigid, maintaining a perpendicular position to the bottom of the tank. Sometimes death would occur in this position. Otherwise the fish died dorsal-side up, giving the appearance of resting. As with the bluegill, some pectoral and caudal fins were hemorrhaged.

In the catfish and bluegill, the time span between the first signs of stress and death was directly proportional to the toxicant concentrations. At high concentrations, death occurred after 2 hours of stress; however at low concentrations, stress might last as long as 12 hours.

RESULTS

The test conditions for the five bioassays using bluegill are summarized in Table 1. For estimating the median lethal time, i.e., that time at which 50% mortality will occur at a particular residual chlorine concentration, the percent mortality was plotted for each concentration on log-probability paper. This procedure is demonstrated in Figures 1a and 1b for bluegill runs on 9/30/74 at 0.79 mg/1 and on 10/7/74 at 0.49 mg/1, respectively. The estimated median lethal time is that time at which 50% of the fishes died. Acute toxicity curves were developed for each bioassay run by plotting the median lethal times on the vertical axis versus corresponding concentrations on the horizontal axis, all on log-log paper. When less than 50% mortality occurred for a particular concentration, the point was plotted on the 96-hr line. The resultant curves, as shown in Figures 2a, 2b, and 3b, permit the determination of

TABLE 1. Test Conditions during Bioassay Runs on Bluegills

Date	Toxicant range (*mg/l*)	Temperature (*°C*)	Avg. fish weight (*grams*)	pH	Alkalinity (*mg/l*)	Hardness (*mg/l*)	Dissolved oxygen (*mg/l*)
9/30/74	0.18-0.79	20	1.85	8.13	317	451	7.5-8.6
10/7/74	0.24-0.79	20	1.85	8.02	310	452	7.5-8.6
10/14/74	0.23-0.77	21	0.31	8.19	313	443	7.5-8.6
10/21/74	0.15-0.51	21	0.31	8.00	306	467	7.5-8.6
11/4/74	0.15-0.51	30	1.24	7.95	316	398	6.4-7.0

median tolerance limits, TL_{50}. The TL_{50} is that concentration at which the toxicity curve becomes asymptotic to the time axis.

As shown in Figures 2a through 3b, median lethal times in all cases for bluegills were less than 96 hours. In most cases, under the conditions of the tests, the median lethal time was 24 hours or less. Nevertheless, the bioassays were continued for at least 96 hours, and the data obtained are reported as the 96-hr TL_{50}.

In the two bioassays using channel catfish, it is probable that concentrations lower than 0.10 mg/1 should have been employed. At 30°C, 60 to 90% of the fishes died at the lower concentration of toxicant used (0.11 mg/1); at 20°C, 100% of the fishes died within 96 hours for all concentrations. Under these circumstances the median tolerance limit is not so clearcut as that determined for the bluegills. A separate bioassay using total residual chlorine concentrations at 0.05 mg/1 and 20°C did not produce any mortality in channel catfish over a 96-hr span. From this it is concluded that a very narrow range of tolerance, from 0.05 to 0.10 mg/1, exists for channel catfish.

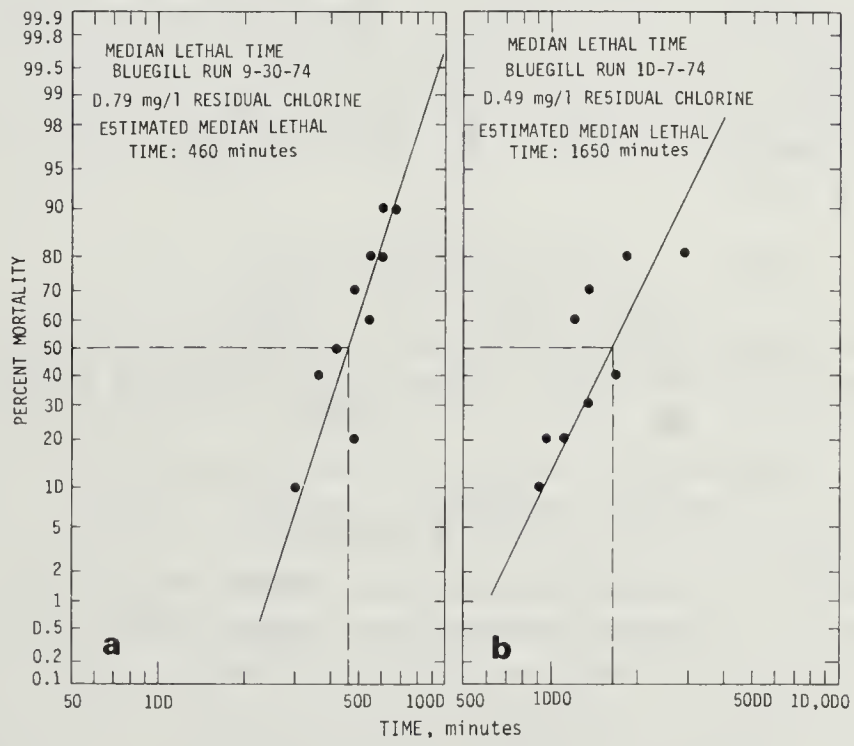

FIGURE 1.--Percent mortality for bluegill.

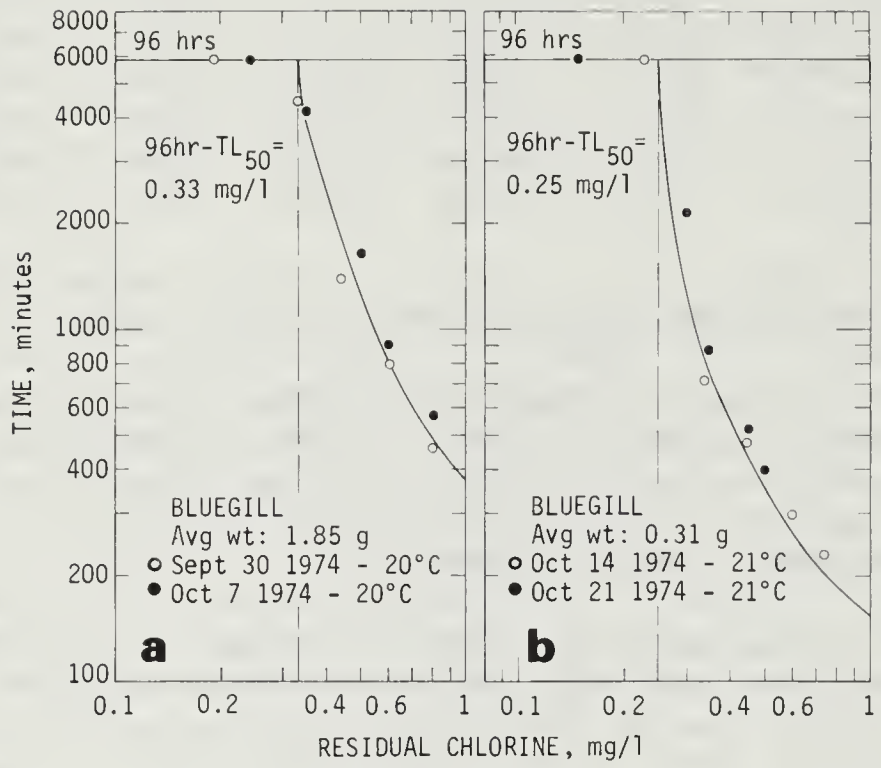

FIGURE 2.--Acute toxicity curves for bluegill showing weight comparisons.

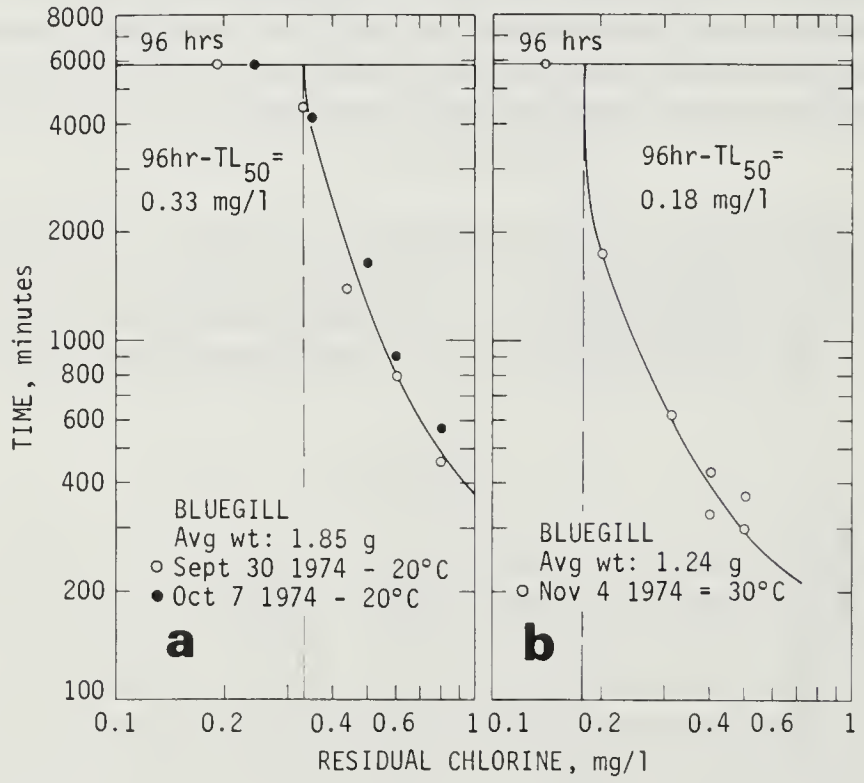

FIGURE 3.--Acute toxicity curves for bluegill showing temperature comparisons.

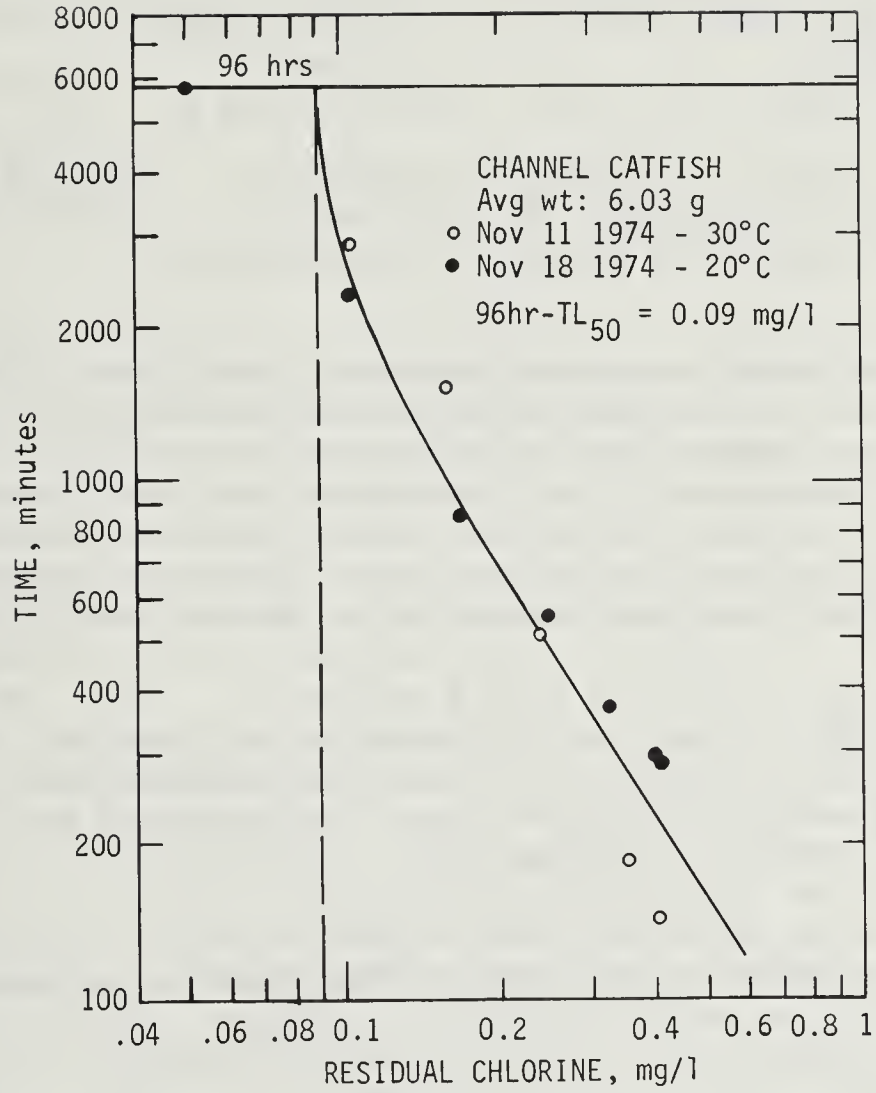

FIGURE 4.--Acute toxicity curve for channel catfish.

Use of procedures as discussed earlier and as shown in Figure 4 gave an estimated median tolerance limit of 0.09 mg/l total residual chlorine. Also, as shown in Figure 4, there is very little difference in plotting the data for 20°C temperature conditions versus 30°C temperature conditions. Therefore, the data were not considered separately.

STATISTICAL METHODS

The assessment of median tolerance limits by graphical methods is an acceptable procedure and where statistical methods are limited, it is the only practicable means for determining limitations on aquatic toxicants. Graphical procedures, however, do not permit quantitative evaluation of the environmental factors that may influence tolerance limits in bioassays. In an effort to determine whether or not significant relationships existed, major portions of the data for bluegill and channel catfish bioassays were subjected to multiple and stepwise linear regression analyses. For this purpose, the dependent variable was the toxicant concentration in mg/l, here designated as TC. The independent variables were (t), time in minutes from the beginning of a bioassay for a change in percent mortality (M) to occur in each tank of water at a temperature (T) in degrees Celsius.

The average weight (W) of all dead fish occurring in a tank was calculated at every change in percent mortality. A single equation was developed in the following form:

$$TC = a - b (\log t) + c (M) - d (T) + e \log W$$

where a, b, c, d, and e are computed coefficients. Data for time (t) and accumulated average fish weight (W) were found to be geometrically distributed and were normalized by use of logarithms.

The three variables, TC, t, and M, used in plotting graphic 96-hour TL_{50} are the first three variables programmed for linear regression analysis. Selection of residual chlorine concentrations in the 0.10 to 0.45 mg/1 range corresponds to that section of the toxicity curve (Figures 2 and 3) which becomes more linear and asymtotic to the time axis in graphic analysis. The best fit of a linear projection across the curve of data points in the graphic toxicity curve (Figures 2 and 3) predicts higher concentration than the observed value around the 0.3 mg/1 residual chlorine interval. It predicts lower residual chlorine concentrations than observed values in the 0.5 to 0.8 mg/1 range. Also, the 96-hour TL_{50} would be predicted lower as evidenced by the curvature of the toxicity curve in graphic analysis. In linear regression analysis, precisely the same predictive results occur when projected from all of the 0.10 to 0.79 mg/1 residual chlorine data.

The inclusion of water temperatures and logs of accumulated average fish weights as independent variables in the equation increases the correlation coefficient and decreases the standard error as evidenced in Table 2. The form of the final equation for bluegill is:

$$TC = 1.1804 - 0.1834 \log t + 0.00147 (M) - 0.01428 T + 0.1560 \log W$$

It should be noted that although there are three average weight groups of 0.31, 1.24, and 1.85 grams (g), the range of fish weight is from 0.10 to 2.9 g. In regression analysis there was a computed average weight of all dead fish for every change in mortality in each of the 27 tanks in 0.10 to 0.45 mg/1 residual chlorine range. Often at high toxicant concentrations, several fish would die at one time, and cause one large change in percent mortality. There were 148 computed average fish weights for the 148 observations of percent mortality change during which 182 of 270 fish died. Therefore, the number of observations for each variable was 148 for time, percent mortality, and accumulated average fish weight and 3 for water temperature. Although the range of fish weight was limited to under 3 g, the smallest fish had the greatest sensitivity to residual chlorine. Thus extension of fish weight range

TABLE 2. Statistical Characteristics of Predictive Equation Bluegill Bioassay

Parameter	F values	Multiple correlation coefficient (r)	Standard error of estimate (SE)
Log time (t)	14.9	0.3045	0.0729
% Mortality (M)	30.9	0.5463	0.0643
Temperature (T)	34.4	0.6460	0.0588
Log fish weight (W)	113.9	0.8725	0.0379

TABLE 3. Comparison of Graphic TL_{50} to Predicted TL_{50} Bluegill Bioassay

Bioassay	Graphic 96-hour TL_{50} (*mg/l*)	Predicted 96-hour TL_{50}* (*mg/l*)
1.85 g @ 20°C	0.33	0.31
0.30 g @ 21°C	0.25	0.26
1.24 g @ 30°C	0.18	0.15

**Based on concentration range 0.144 to 0.440 mg/l*

in that direction is limited since the average weight of all fish in two bioassays was 0.31 g with minimum fish weights of 0.10 g. Similarly, the greatest sensitivity of bluegill was in 30°C water so that extension of water temperature is limited if held to those temperature maximums observed in native Illinois streams and lakes. Linear regression analysis insures that eye-hand coordination used in graphic 96-hour TL_{50} determinations is understood in terms of effect on the desired determination of toxicant levels.

The predicted residual chlorine values were calculated on the basis of 148 times at which 148 changes in percent mortality occurred in fish with 148 computed average weights at 3 water temperatures. The comparison of these predicted residual chlorine values and the observed residual chlorine level at the time of each change of percent mortality is illustrated in Figure 5. Table 3 compares the similarity of 96-hour TL_{50} values as predicted by linear regression analysis and graphic analysis.

Table 2 shows the increase in F factor and correlation coefficients as time, percent mortality, accumulated average fish weight, and water temperature were included. The ranking of parameters on the basis of toxicant level effect was 1) log time, 2) percent mortality, 3) log of accumulated average fish weight, and 4) water temperature. When each of

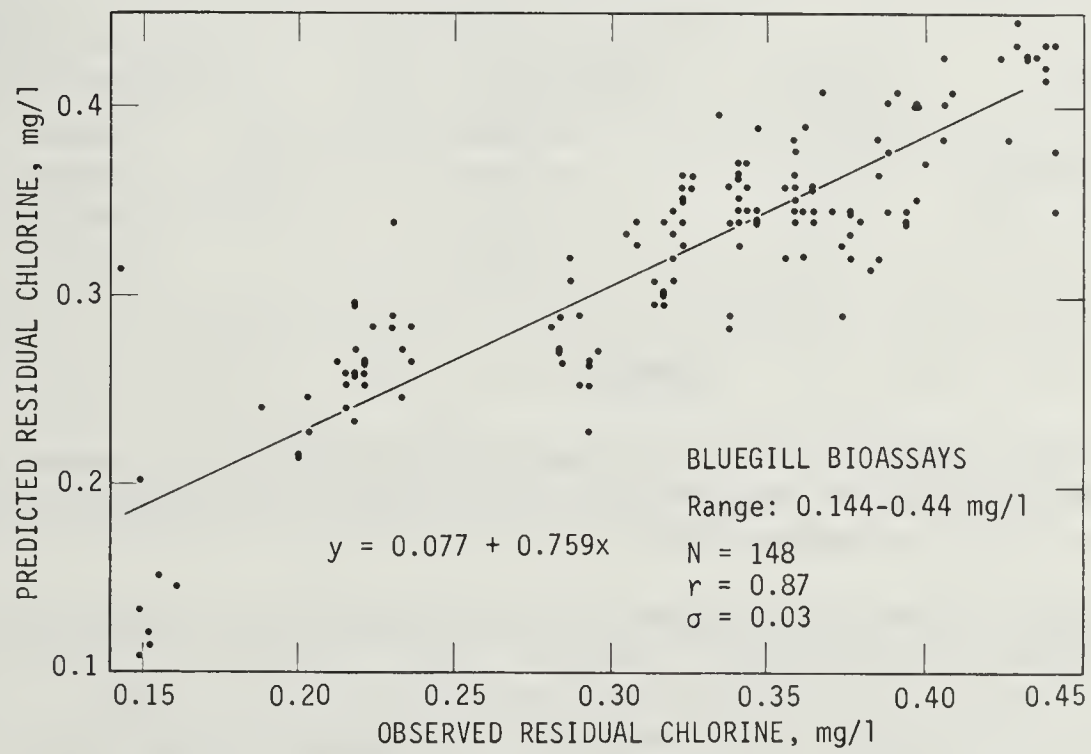

FIGURE 5. Predicted residual chlorine from all percent mortality changes from all bioassays versus observed residual chlorine.

the 3 fish weight and water temperature groups were processed separately by linear regression analysis, only log time and percent mortality significantly increased r in the 1.85 g average weight fish at 21°C and the 1.24 g average weight fish at 30°C. In fish of average weight 0.31 g at 21°C, the log of average fish weight increased r by 0.10 so that the 96-hour TL_{50} of that group was dependent upon log time, percent mortality, and log of average fish weight in that order of importance.

Similar analyses of the channel catfish data indicate that the toxicant concentration relationships with t, M, T, and W are different from that determined by bluegill bioassays. The order of importance is 1) time, 2) mortality, 3) weight, and 4) temperature. With channel catfish, water temperature appeared to be only marginally significant as shown in Table 4. It was not included in the equation.

The predictive equation developed for channel catfish bioassays is:

$$TC = 0.8753 - 0.264 \log t - 1.00103 M + 0.2133 \log W$$

The channel catfish, reflecting a 96-hour TL_{50} of about 0.09 mg/1 residual chlorine in contrast to a 96-hour TL_{50} range for bluegill of 0.18 to 0.33 mg/1 residual chlorine, is obviously the more sensitive fish. The water pollution regulations require an application factor of one-tenth in establishing a maximum permissible concentration. The permissible concentration of residual chlorine for channel catfish protection would be about 9 micrograms per liter, and that for the protection of bluegill would range from 18 to 33 micrograms per liter in Illinois streams. Thus, for all practical purposes, residual chlorine should not be detectable in any stream in Illinois.

TABLE 4. Statistical Characteristics of Predictive Equation Channel Catfish Bioassay

Parameter	F values	Multiple correlation coefficient (r)	Standard error of estimate (SE)
Log time (t)	470.9	0.9019	0.0492
Percent mortality (M)	69.8	0.9418	0.0385
Log fish weight (W)	46.2	0.9598	0.0324
Temperature (T)	6.3	0.9622	0.0315

SUMMARY

1) Bluegill and channel catfish were subjected to varying concentrations of residual chlorine in waters relatively high in alkalinity and the salts of calcium and magnesium.

2) Acute toxicity curves were developed for each species permitting assessment for 96-hour TL_{50}.

3) In the case of bluegills, the 96-hour TL_{50} ranged from 0.18 to 0.33 mg/1 and was dependent upon water temperature and fish weight.

4) In the case of channel catfish, a more sensitive fish to residual chlorine, the 96-hour TL_{50} was about 0.09 mg/1. Temperature was not a factor.

5) For each type of fish species, predictive equations were developed that permitted the quantitative evaluation of environmental factors within the experimental boundaries of the 96-hour TL_{50} bioassays.

6) For the protection of the fishes investigated and consistent with the water pollution regulation of Illinois, residual chlorine in Illinois streams should not be detectable.

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RESPONSE OF A SOUTHERN ILLINOIS GRASSLAND COMMUNITY TO BURNING

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ABSTRACT.--Changes in species quadrat frequency, density of woody stems, grass flowering culms, and legumes, and height of *Sorghastrum nutans* flowering culms were examined on control and burned grassland plots. Sampling was carried out during the growing season, in 1969 and 1970, prior to and following burning. Above ground production was sampled monthly June through September in 1970. Following burning, species showing the greatest increase in frequency included annual and somewhat weedy legumes, and *Sassafras*, as the result of resprouting. Species decreasing after burning are primarily associated with woodland or disturbed habitats, although two species of goldenrods found on prairie had sizable declines in frequency. Legume density markedly increased from 108,396 to 291,000 stems per ha (43,885 to 158,300 per acre) following burning. Two prairie grasses, *Schizachyrium* and *Sorghastrum*, did not have a pronounced increase in flowering culms following burning as has been recorded by previous workers. However, *Panicum lanuginosum* had a sharp decline from 45,486 to 2,668 culms per ha (18,415 to 1,080 per acre). Above ground biomass was consistently higher on the burned plots. Legume production was always at least seven times greater on the burned than unburned site. All woody stems greater than 15.2 cm (six in.) tall, but less than 1.27 cm (.5 in.) dbh, were destroyed by the fire. However, resprouting was prolific in *Sassafras*.

INTRODUCTION

Several studies have examined the role of fire in tallgrass prairies in the Midwest (Curtis and Partch, 1948; 1950; Ehrenreich, 1959; Kucera and Ehrenreich, 1962; Hadley and Kieckhefer, 1963; Kucera and Koelling, 1964; Kucera and Dahlman, 1968; Old, 1969; Anderson, 1972b; Peet *et al*, 1975). These workers report that following fire, increased production

of major grass species and control of woody species and herbaceous exotics occurs. However, only a limited number of studies (Kucera and Koelling, 1964; Cottam and Wilson, 1967; Anderson and Cottam, 1968) have considered the response of more than just the most dominant members of the prairie, and even fewer have been carried out at the humid southern limit of prairies in Illinois (Anderson and Schwegman, 1971; Anderson, 1972). The purpose of this study was to document changes in species composition following burning for an area dominated by prairie species, but experiencing invasion by woody plants and exotics in southern Illinois.

DESCRIPTION OF THE STUDY AREA

The study plots are located in Section 26, Township 10 South, Range 1 West on the Southern Illinois University Arboretum research station, ten miles southeast of Carbondale.

Forests covered much of southern Illinois before settlement by Europeans. Interfingering areas of continuous prairie vegetation did not extend much further south than Carbondale (Anderson, 1970; Anderson and Anderson, 1975). Vestal (1936) described a barren vegetation type occurring further south than the contiguous tallgrass prairie. Barrens had more trees and shrubs than prairies, and lacked some characteristic prairie species such as prairie dock (Silphium sp.) (Vestal, 1936). Anderson (1970) working with the original land survey records, suggested barren areas were scattered throughout southern Illinois. He concluded the disappearance of the barrens was due to cessation of annual burning by aboriginals (Gleason, 1913; 1923; Sauer, 1950; Curtis, 1959; Vogl, 1964; Anderson, 1970; Vogl, 1974).

Government land office records indicate all four corners of the Section, in which the study area is located, was forested. Therefore, prairie species found on the area represent a small prairie or barren area not recorded by the surveyors, or perhaps, a successional community. Plots were located within an opening bordered by a forested stream bank on two sides, and abandoned fields, containing some prairie species, on the remaining sides. The study area has a southwest facing aspect with a zero to five percent slope.

Principal soil types are Alford and Sharon silt loams with an underlying mantle of loess approximately 381 to 762 cm (150 to 300 in.) deep (Soil Survey Staff, 1960; Smith, 1942). Indian grass (Sorghastrum nutans) and little bluestem (Schizachyrium scoparium = Andropogon scorparius) are the dominant prairie grasses, with goldenrods (Solidago juncea and S. altissima) being dominant forbs on the study area. Trees such as sassafras (Sassafras albidum) and persimmon (Diospyros virginiana)are found scattered throughout the area.

Prior to 1930 the site was in private ownership, but the exact usage of the study area is unknown. From 1930 to 1950 the land remained in private ownership, however, it was not put to any agronomic use. In 1950 Southern Illinois University assumed ownership of the land (Hart, J., 1972, personal communication). Since the advent of Southern Illinois University ownership, the land was ostensibly undisturbed until the present study began in 1969.

METHODS

The study site, which measured 51.8 X 79.3 m (170 X 260 ft.), was divided into four plots with six permanent sampling points located in standard positions to insure uniform coverage of the area. All tree stems greater than 8.9 cm (3.5 in.) dbh were measured. Woody stems less than 8.9 cm (3.5 in.) were sampled, by size class, in two circular nested quadrats, 81 and 40.5 m^2 (1/50 and 1/100 acre) in size, centered at each sampling point. Seedlings, saplings, and shrubs were placed into one of five size classes: (1) > 15.2 cm (6 in.) tall but < 1.4 m (4.5 ft.), (2) $\geq$ 1.4 m (4.5 ft.) tall but < 1.3 cm (.5 in.) dbh, (3) $\geq$ 1.3 cm (.5 in.) but < 3.8 cm (1.5 in.) dbh, (4) $\geq$ 3.8 cm (1.5 in.) but < 6.4 cm (2.5 in.) dbh, (5) $\geq$ 6.4 cm (2.5 in.) but < 8.9 cm (3.5 in.) dbh. Stems in size classes one and two were sampled in 40.5 m^2 (1/100 acre) quadrats and stems in other size classes were sampled in 81 m^2 (1/50 acre) quadrats.

At each sampling point, ten .4 m^2 (1/10,000 acre) quadrats, placed at standard position within the 81 m^2 (1/50 acre quadrat), were utilized to determine frequency of grasses, forbs, and woody vegetation less than 15.2 cm (6 in.) tall. Density counts of legume stems and flowering grass culms were also recorded.

In August, 1969, before burning, plots were sampled and 20 mature flowering culms of Indian grass measured at each permanent sampling point to determine average height. On December 1, 1969, the designated plots were burned. The burn was clean and hot with nearly complete consumption of litter. Outside the perimeter of the 40.5 m^2 (1/100 acre) quadrat, meter square quadrats were arranged so herbaceous above ground biomass could be harvested monthly without interfering with the .4 m^2 (1/10,000 acre) quadrats. The position of these quadrats was adjusted so competitive woody vegetation would not be included. Harvesting began in June, 1970, and continued monthly through September, 1970. Ten meter square quadrats were clipped from each of the control and burn areas. Vegetation was separated into four groups: grasses, legumes, goldenrods, and other, oven dried at 75 degrees C for 36 hours and weighed.

RESULTS

Woody Vegetation

Woody vegetation in all size classes remained unchanged on the control plot during the study period, as shown in figure 1. Similarly, on both control and burned plots no change was recorded on the few stems greater than 8.9 cm (3.5 in.) dbh.

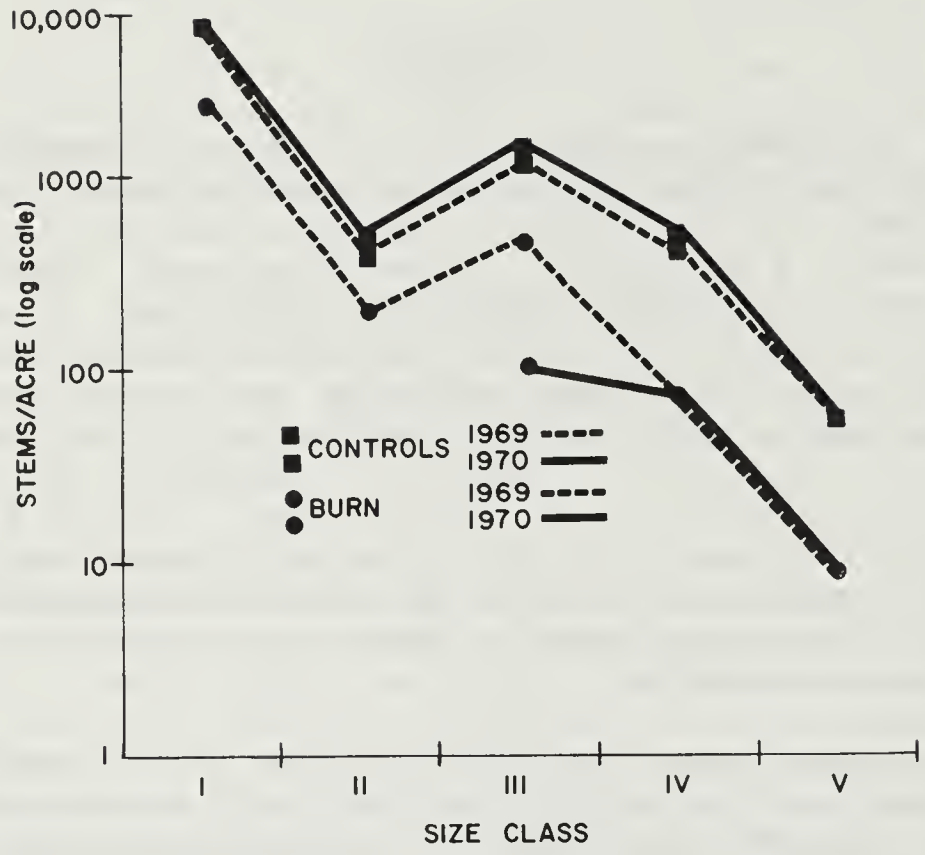

Figure 1. Woody stems by size class on the control and burned plots during the study period. Stems per acre X 2.47 equals stems per ha.

However, the density of woody stems on the burn site changed considerably. Shoots of trees and shrubs in size class I and II, as given by Table 1, were destroyed by the fire. In classes I and II, 6,010 tree and shrub stems per ha (2,433 per acre) were killed by the fire. Resprouting was observed only in Sassafras, but stems of this species did not reach size class I by the post fire sampling date. Sassafras sprouts sampled in the .4 m^2 (1/10,000 acre quadrats), increased in frequency from nine percent to 36 percent. This response of sassafras after a fire, or other disturbances, is not unusual in southern Illinois (Ashby and Kelting, 1963). According to Fowells (1965) persimmon should also exhibit resprouting following fire, but this was not observed.

As in the previous size classes, size class III stems were reduced from 1,069 to 247 stems per ha (433 to 100 per acre) following burning. Diospyros and Sassafras were found in about equal numbers prior to the fire, but following the burning, Sassafras survived slightly better 124 versus 91 stems per ha (50 versus 37 stems per acre). The higher survival rate may be due to localized intensity of the fire caused by greater amounts of accumulated litter. In size class IV a slight reduction occurred in total stems per ha with persimmon surviving in higher numbers than Sassafras. No mortality was observed in size class V.

TABLE 1. Density (stems per ha) of woody species by size class on the burned plots. Values in parenthesis are stem per acre.

Species	1969 Class Size				
	1	2	3	4	5
Acer rubrum*	41 (16)	-	-	-	-
Carya glabra	-	-	-	20 (8)	-
Carya ovalis	-	-	-	-	10 (4)
Corylus americana*	20 (8)	-	-	-	-
Crataegus mollis*	20 (8)	-	-	-	-
Diospyros virginiana	412 (166)	144 (58)	504 (204)	124 (50)	-
Juniperus virginiana*	82 (33)	-	-	-	-
Quercus velutina	62 (25)	-	10 (4)	10 (4)	10 (4)
Rhus aromatica*	144 (58)	-	-	-	-
Rosa multiflora*	268 (108)	-	-	-	-
Rubus pennsylvanicus*	288 (116)	-	-	-	-
Sassafras albidum	3932 (1592)	309 (125)	483 (196)	31 (12)	-
Ulmus alata	268 (108)	-	72 (29)	10 (4)	10 (4)
Total	5558 (2250)	453 (183)	1070(433)	195 (79)	31 (12)
	1970				
Carya glabra	-	-	-	20 (8)	-
Carya ovalis	-	-	-	-	10 (4)
Diospyros virginiana	-	-	93 (38)	124 (50)	-
Quercus velutina	-	-	-	10 (4)	10 (4)
Sassafras albidum	-	-	124 (50)	20 (8)	-
Ulmus alata	-	-	31 (12)	-	10 (4)
Total	-	-	247 (100)	174 (70)	31 (12)

*Species with an asterisk were completely removed from the seedling and sapling size classes by the fire.

Herbaceous Vegetation

In Table 2 quadrat frequencies for herbaceous plants and woody stems less than 15.2 cm (6 in.) tall is given. Frequency of herbaceous vegetation on the control plot remained relatively unchanged for both sample years (Table 2). Species having a five percent change in quadrat frequency on the burned site are listed first. From the table it can be seen that Sassafras had a substantial frequency increase, 36.7 percent. Thus, although it declined in density in the seedling and sapling classes I through IV, its resprouting capacity is demonstrated by the abundance of stems less than 15.2 cm (6 in.) tall. Another woody species which showed a slight increase in response to burning was Rubus flagellaris.

Herbaceous species increasing in frequency include three general groups: (1) annual or somewhat weedy legumes, such as Cassia fasiculata, C. nictitans, Lespedeza stipulaceae, L. procumbens, L. striata, and Strophostyles leiosperma, (2) annual weeds, Oxalis stricta and Ambrosia artemisiifolia, and (3) prairie species, including Schizachyrium scoparium, Pycnanthemum pilosum, and Solidago juncea.

The species with the greatest decrease in frequency following burning was Panicum lanuginosum. This species has been segregated into several varieties which occupy a wide array of habitats including wet prairies (Steyermark, 1968). Other species decreasing on the burned site are found in (1) disturbed habitats, Acalphya virginica, Andropogon elliotii, and Solidago altissima and S. nemoralis, or in (2) open or closed woodlands, Desmodium nutallii, D. rigidium, Eupatorium rugosum, Elymus virgincus, Galium pilosum, and Parthenocissus quinquefolia. Both of the species of Desmodium are perennial. Surprisingly the two goldenrods decreasing in frequency also occur in prairies.

The change in the density of legume and grass flowering culms per ha is shown in Table 3. For most of the grass species, including Schizachyrium scoparium and Sorghastrum nutans, there is little change in the number of flowering stems. Exceptions to this generalization are Panicum anceps which had a sizable increase in flowering culms per ha on the burned sites 2,050 to 7,818 (830 to 3,165 per acre), and Panicum lanuginosum which markedly decreased 45,485 to 2,668 (18,415 to 1,080 per acre). Elymus virgincus, Andropogon elliotii and Eragrostis spectablis also showed some change in flowering culm density. E. virgincus and A. elliotii decreased 2,260 to 0 culms per ha (915 to 0 per acre) and 2,878 to 198 (1.165 to 80 per acre) respectively, while the lovegrass increased 0 to 2,668 per ha (0 to 1,080 per acre). Total number of grass flowering culms on the burned and control plots remained about the same during the study, Table 3.

In contrast there was a pronounced increase in total number of legume stems on the burned plot. Stems per ha increased from 108,397 to 391,077 (43,885 to 158,330 per acre) following burning. However, total density of legumes remained about the same on the control. Most of the increase on the burned site was due to the two annual species of Cassia, Lespedeza procumbens, and L. stipulaceae. Melilotus officinalis and Desmodium rigidum declined in stem density following burning.

TABLE 2. Frequency values for the two study sites.

Species	Control		Burn		
	1969	1970	1969	1970	Change
(A) Quadrat frequency values for species having a 5% change between years on the burned plot.					
BURNING INCREASERS					
Cassia nictitans	1.6	2.5	6.6	44.1	+37.5
Sassafras albidum	8.5	6.6	9.1	45.8	+36.7
Cassia fasiculata	1.8	1.8	.8	31.6	+ 30.8
Strophostyles leiosperma	4.6	4.6	2.4	27.5	+ 25.1
Oxalis stricta	7.6	10.3	10.8	35.8	+ 25.0
Lespedeza stipulucea	8.8	9.6	3.3	24.9	+ 21.6
Ambrosia artemisiifolia	8.5	9.3	3.9	23.3	+ 19.4
Panicum anceps	.8	.8	1.6	16.6	+ 15.0
Lespedeza procumbens	2.8	3.8	12.4	25.8	+ 12.4
Solidago juncea	21.8	17.6	27.5	49.1	+ 11.6
Lespedeza striata	0	0	0	10.8	+ 10.8
Schizachyrium scoparium	5.0	7.8	16.6	24.9	+ 8.3
Pycnanthemium pilosum	12.0	7.1	3.3	11.6	+ 8.3
Rubus flagellaris	45.3	44.3	50.0	55.8	+ 5.8
BURNING DECREASERS					
Panicum lanuginosum	24.6	26.3	42.5	.8	- 41.7
Desmodium rigidum	5.0	4.1	23.3	1.6	- 21.7
Solidago altissima	23.8	23.0	28.3	11.6	- 16.7
Melilotus officinalis	15.0	15.0	17.5	3.3	- 14.2
Solidago nemoralis	12.5	11.0	22.4	9.1	- 13.3
Acalypha virginica	27.5	29.1	22.5	10.0	- 12.5
Andropogon elliotii	3.5	4.5	9.9	.8	- 9.1
Smilax glauca	5.8	6.6	11.6	2.5	- 9.1
Desmodium nuttallii	3.5	1.6	7.5	0	- 7.5
Parthenocissus quinquefolia	14.6	13.8	7.5	0	- 7.5
Eupatorium rugosum	16.5	11.8	6.6	0	- 6.6
Galium pilosum	2.6	2.6	11.6	5.8	- 5.8
Elymus virgincus	3.0	3.8	5.8	0	- 5.8
(B) Other species showing less than 5% change listed alphabetically.					
Achillea millefolium	1.0	1.0	-	-	
Allium vineale	2.6	3.6	1.4	2.5	
Ambrosia trifida	1.0	1.0	-	-	
Andropogon virginicus	1.0	1.0	.8	-	
Anemone virginiana	2.0	1.0	-	-	
Arabis laevigata	.8	.8	-	-	
Aristida oligantha	-	-	.6	-	
Ascelepias syriaca	7.1	8.1	-	-	
Asclepias tuberosa	1.6	.8	2.2	4.1	
Asparagus officinale	1.0	2.8	-	-	
Asplenium platyneuron	1.6	-	4.1	-	

TABLE 2 (continued)

Species	Control		Burn	
	1969	1970	1969	1970
Aster pilosus	-	1.6	2.2	2.4
Botrychium obliquum	2.6	1.0	.6	-
Carex bushii	-	-	.8	-
Carex glaucoidea	2.8	1.0	.8	-
Carex umbellata	2.0	3.0	-	-
Circium discolor	1.8	2.8	2.5	4.1
Convolvulus arvensis	6.1	6.1	1.4	-
Corylus americana	-	-	.6	-
Cystopteris fragilis	10.8	11.0	-	-
Danthonia spicata	4.0	4.0	-	-
Daucus carota	1.6	.8	-	-
Desmodium glabellum	-	-	.6	-
Desmodium illinoense	.8	-	3.3	-
Desmodium paniculatum	-	-	.6	-
Diodea teres	1.0	1.0	-	-
Diospyros virginiana	1.0	-	-	-
Eragrostis spectabilis	1.0	1.0	.6	1.6
Erechtites hieracifolia	1.0	-	-	-
Euphorbia corollata	12.8	10.5	9.1	13.3
Geum canadense	5.5	3.8	4.1	-
Gnaphalium obtusifolia	-	-	.8	-
Hedioma pugilloides	1.0	.8	-	-
Helianthus divaricatus	-	-	1.6	-
Hypericum puncatatum	1.6	.8	.6	2.5
Juncus tennuis	-	-	.6	-
Juniperus virginiana	1.0	2.0	-	-
Latuca canadensis	-	-	.8	.8
Lespedeza repens	-	-	.8	-
Lespedeza violacea	2.0	2.0	-	4.9
Lespedeza virginica	-	-	.6	-
Lobelia inflata	-	-	.8	.8
Lonicera japonica	6.0	6.0	-	-
Oenothera biennis	.8	-	-	-
Panicum capillare	1.8	1.8	.8	1.6
Panicum xalapense	3.5	4.1	2.2	-
Physallis heterophylla	5.5	3.0	.8	-
Phryma leptostachya	3.0	3.0	-	-
Poa compressa	1.0	1.0	.8	-
Potentilla simplex	1.0	-	-	-
Rhus aromatica	.8	-	-	-
Rhus radicans	15.6	18.3	.8	-
Rudbeckia hirta	2.5	1.6	.8	5.0
Rumex acetosella	3.3	2.5	2.5	-
Rosa multiflora	5.0	5.0	.6	-

TABLE 2 (continued)

Species	Control		Burn	
	1969	1970	1969	1970
Sanicula canadensis	7.0	7.0	.8	-
Setaria viridis	1.6	1.6	-	-
Solanum carolinense	.8	-	.8	-
Sorghastrum nutans	91.0	93.0	97.4	96.6
Ulmus alata	7.5	6.6	2.5	-
Verbena urticifolia	2.0	3.0	.8	.8
Vitus cinerea	2.8	2.8	.8	-

Herbaceous Production

Above ground production was higher on burned plots than control for all categories (grasses, legumes, goldenrods) and for all sampling dates, as shown in Table 4. Peak standing crop occurred during September, and the burned site had more than twice the above ground biomass of the control at this date, 496.7 g/m^2 (4.429.1 lbs/acre) compared to 248.6 g/m^2 (2,216.7 lbs/acre). Within biomass categories, largest differences occurred in legume production. Legume production was always at least seven times greater on burned than control plots.

Height of grass flowering culms varied little between years, or between burned and control sites. On the control plot average height of Sorghastrum nutans flowering culms was 157 cm (61.8 in.) in 1969 and 156 cm (61.4 in.) in 1970. For the same years on the burned site average culm heights were 157 and 154 cm (61.8 and 60.6 in.) respectively.

DISCUSSIONS AND CONCLUSIONS

Mutch (1970) proposed a hypothesis that plant communities dependent on fire burn more readily because natural selection has developed in them characteristics which increase their flammability. He suggests the following examples of communities that produce highly flammable fuels: grasslands, ponderosa pine forests, Eucalyptus obliqua forests, and savanna woodlands. These fire dependent systems have evolved fire resistant mechanisms such as thick bark and below ground perennating buds.

Results from this study reveal that several species responded positively to fire by displaying increased frequency, density, and above ground biomass, or any combination of the above. Sassafras was the only woody species to show vigorous resprouting following the fire. The pronounced decline in woody species following the burn may be due in part to heavy litter accumulation, resulting from years of fire protection, that would result in a very hot fire (Wright and Bunting, 1975). No woody stems in the seedling classes survived the fire, however, woody stems in sapling classes, III, IV, and V were able to endure

TABLE 3. Change in grass flowering culms and legume density in the control and burned plots. Stems/ha (stems/ha ÷ 2.47 = stems/acre).

	Control			Burn		
	1969	1970	Change	1969	1970	Change
Grass (flowering culms)						
Andropogon elliotii	-	1,186	+1,186	2,878	198	-2,680
Elymus virginicus	741	988	+ 247	2,260	-	-2,260
Eragrostus spectabilis	370	370	0	-	2,668	+2,668
Panicum anceps	-	-	-	2,050	7,818	+5,767
Panicum capillare	445	445	0	2,668	2,668	0
Panicum lanuginosum	24,206	18,402	+5,804	45,485	2,668	-42,817
Panicum xalapense	198	408	+ 210	815	-	-815
Schizachyrium scoparium	8,398	7,163	-1,235	18,315	19,550	+1,235
Setaria viridis	408	198	- 210	-	-	-
Sorghastrum nutans	239,998	244,036	+4,038	284,865	289,978	+5,113
Totals stems/ha	274,764	273,196		359,336	325,548	
Legumes						
Cassia fasciculata	445	692	+ 247	198	96,454	+96,256
Cassia nictitans	408	815	+ 408	198	42,361	+42,163
Desmodium glabellus	-	-	-	815	-	- 815
Desmodium illinoense	815	-	- 815	815	-	- 815
Desmodium nuttallii	1,680	618	-1,062	4,520	-	- 4,520
Desmodium paniculatum	-	-		1,025	-	- 1,025
Desmodium rigidum	2,878	1,025	-1,853	22,638	2,050	-20,588
Lespedeza procumbens	12,301	11,276	-1,025	51,660	191,796	+140,136
Lespedeza repens	-	-	-	1,025	-	- 1,025
Lespedeza striata	-	-	-		14,610	+14,610
Lespedeza stipulacea	3,001	5,632	+2,631	5,965	26,948	+20,983
Lespedeza violacea	741	741	0	-	6,990	+ 6,990
Melilotus officinalis	15,808	16,055	+ 247	18,933	1,433	-17,500
Strophostyles leiosperma	1,149	1,803	+ 654	605	8,435	+ 7,830
Totals stems/ha	39,226	38,656		108,397	391,077	

TABLE 4. Above ground biomass production during 1970, g/m^2.

	June	July	August	September
Grasses				
burn	82.68	139.86	207.03	276.62
control	59.93	67.18	158.94	184.15
Legumes				
burn	30.91	46.48	76.38	91.18
control	.80	6.03	9.64	9.97
Goldenrods				
burn	69.94	63.64	76.19	106.14
control	6.02	13.80	23.35	18.11
*Total				
burn	226.58	270.48	387.14	496.77
control	104.46	121.24	237.36	248.60

*Total includes others.

the burn. These results suggest the woody component of the area is unlikely to be eliminated by burning alone, and adds credence to the view the site was historically a barren area, containing both woodland and prairie species.

Of the herbaceous vegetation Cassis fasiculata and C. nictitans showed the greatest response to burning, both increased over 30 percent in frequency after burning. These annual species increased in stems per ha 198 to 96,454 (80 to 39,050 per acre) and 198 to 42,361 (80 to 17,150 per acre) respectively. The post fire increase of legumes has been documented by Lemon (1967) in Africa, McKell et al (1962) in California, and in southern Illinois by Anderson and Schwegman (1971). However, Kucera and Koelling (1964) and Kucera (1970) did not find a post fire increase in legumes in a Missouri tallgrass prairie. Increase in annual legumes may be due to a release from competition in the more open environment caused by the fire. Martin and Cushwa (1966) and Martin et al (1975) found moist heat, such as would affect seeds in the soil during a fire, increases germination rates of some legume seeds. But of fourteen species of legumes found in the study area, seven decreased in frequency and density (Table 2) and of these decreasers five are species of Desmodium. However, several of these legume species occurred infrequently in the sample. All species of Lespedeza increased in density and frequency except Lespedeza repens which was found in low numbers before the fire and was not observed thereafter.

Of the two major prairie grasses only little bluestem showed an increase in frequency or density of flowering culms. Little bluestem increased 8.3 percent in quadrat frequency following burning and Indian grass decreased slightly.

Flowering culms of little bluestem increased from 18,315 to 19,550 stems per ha (7,415 to 7,915 per acre) on the burned plot, but decreased from 8,398 to 7,163 stems per ha (3,400 to 2,900 per acre) on the control plot. Possibly, a fluctuation of 1,235 stems per ha (500 per acre) may be a "normal" variation and not attributable to the fire. This is in contrast to Kucera and Ehrenreich (1962) in Missouri and Dix and Butler (1954) in Wisconsin who found a greater increase in flowering of little bluestem. Ehreneich (1959) indicates the increase in flowering following a spring burn is caused by increased soil temperatures with removal of litter. Old (1969) also found an increase in the flowering of prairie grasses in central Illinois and attributed the increase to an alteration in microclimate through litter removal. She found that burned sites warmed up more rapidly in the spring. The warmer temperatures enhance the activity of soil microorganisms and hence the availability of inorganic nutrients as a result of increased rates of organic matter decomposition. Significantly the soil nitrogen level of burned prairie plots was higher than on unburned plots and the addition of nitrogen fertilizer was shown to increase flowering. In contrast, Daubenmire (1968), believes the reason is yet undetermined.

Indian grass increased approximately the same on the control and burned plot in density and frequency, suggesting little effect from the fire with regard to these two parameters. Indian grass flowering after

burns has been shown to increase in Illinois (Hadley and Kiekhefer, 1963) and decrease in Wisconsin on a dry prairie site (Dix and Butler, 1954).

The grasses which displayed greatest increase and decrease in frequency and numbers of flowering culms were both members of the genus Panicum. Increasing in frequency by 15 percent and in density from 2,050 to 7,818 flowering culms per ha (830 to 3,165 per acre) was Panicum anceps, while P. Lanuginosum decreased 42 percent in frequency and from 45,485 to 2,668 per ha (18,415 to 1,080 per acre). This is in general agreement with Swan (1970) who found that Panicum lanuginosum decreased 31 percent after a fire in New York.

Biomass of various prairie grasses has been shown to increase following fire by several workers (Hadley and Kieckhefer, 1963; Old, 1969; Swan, 1970; Vogl, 1974). They also note increased flowering along with the weight increase. In this study the weight of the grasses increased on the burned plot. Comparison of culm length measurements given in the results, suggest the weight increase is not attributable to an increase in height in Indian grass, however, only flowering culms were measured. Aldous (1934) found burning increased both the size and number of leaves of little bluestem and big bluestem (Andropogon gerardi), which increased leaf area per plant 64 percent and 23 percent respectively. Such a response then, may account for the weight gain without the concomitant increase in flowering culms or in their height as observed in this study.

Biomass difference between legumes on the burned and control plot is most striking. It was suggested earlier that the open environment (reduction in competition) resulting from burning is, at least in part, responsible for the increase in annual legumes such as species of Cassia and Lespedeza. The Desmodiums, which all decreased, are perennial, tending to support the hypothesis that the fire opens the stand and allows annuals to become established.

Several species of goldenrods including Solidago juncea, S. nemoralis and S. altissima have been shown to increase in frequency following a fire in southern Illinois (Anderson and Schwegman, 1971). In this study the biomass of the goldenrods increased as a group, but only Solidago juncea increased in frequency, both S. altissima and S. nemoralis decreased in frequency. Swan (1970) found some species of goldenrod increase after a fire but, depending on the competition, some remain neutral. Perhaps the decrease in the two species of goldenrod may be due to active competition, especially from the rapidly increasing legumes and vigor of grasses following fire.

The results presented here are only for a single season and additional burning may have changed the pattern of species dominance. Many of the weedy annuals such as Ambrosia artemisiifolia, might be expected to decline as the perennial species, especially the grasses, become increasingly important (Anderson and Cottam, 1968; Anderson and Schwegman, 1971) The role of annual legumes in the grassland ecosystem needs further attention, since high rates of nitrogen fixation may be associated with some of the species showing a marked increase in density following burning (Becker and Crockett, 1976).

In spite of some differences in the response of individual species reported here and in the literature, our work generally supports the hypothesis that periodic burning is an integral part of the grassland ecosystem. Burning was shown to increase production of grass and legume species and it also reduced the vigor of competitive woody vegetation. However, it appears that a universal formula to predict the response of many species to fire does not presently exist.

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ARAPAHO ROCK GLACIER, COLORADO FRONT RANGE

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ABSTRACT

Considerable field evidence, such as ridge and furrow patterns, steep fronts, lichen growth, and other data from plane table surveys, along the Colorado Front Range shows that rock glaciers there have moved in the past and are presently moving. This study shows that Arapaho rock glacier which occupies part of a cirque at the head of Arapaho Valley west of Boulder, Colorado, has an ice glacier buried beneath rock cover in the upvalley one-third of glacier and the downvalley two-thirds contains rock debris and interstitial ice. The buried glacier may be helpful, but is not essential, in the movement of this rock glacier, rather, interstitial ice is probably the primary factor. Arapaho rock glacier may have originated when interstitial ice developed in accumulations of talus at the front of the present buried rock glacier.

INTRODUCTION

Arapaho rock glacier lies at 40° 1' 12" north latitude and 105° 37' 30" west longitude and occupies the southernmost part of a double cirque at the head of Arapaho Valley, North Boulder Creek (Fig. 1). The purpose of this paper is to discuss the origin of Arapaho rock glacier and the evidence and origin of its movement. The data were compiled through field observations and plane table surveys by this investigator and Sidney E. White during the summers of 1964-65-66 (Wallace, 1967). The original data have been supplemented through correspondence with Sidney E. White from 1967 to the present.

ROCK GLACIERS DEFINED

Potter (1972) defines a rock glacier as "a tongue-like or lobate body usually of angular boulders that resembles a small glacier, generally occurs in high mountainous terrain, and usually has ridges, furrows, and sometimes lobes on its surface, and has a steep front at the angle of

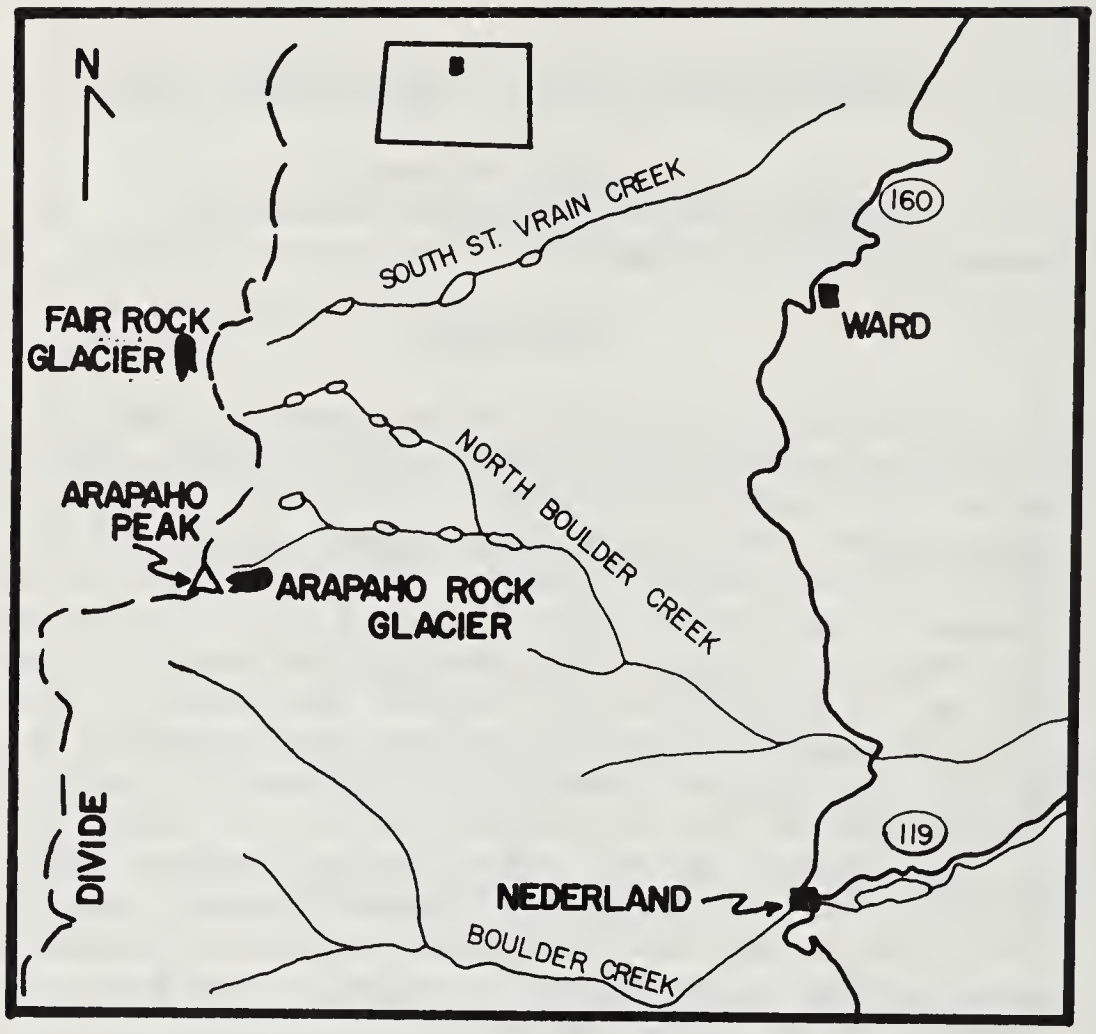

FIG. 1 LOCATION MAP

repose." Wahrhaftig and Cox (1959) in their studies in the Alaska Range, Alaska, group rock glaciers into three types on the basis of shape, ratio of length to breadth, and topographic position. Lobate rock glaciers are either single or multiple lobed features that originate in talus at the base of steep valley walls. Many rock glaciers of this description occur in the Colorado Front Range (Wallace, 1967; White, 1976). Tongue-shaped rock glaciers are much longer than they are wide and occupy cirques (Fig. 2). The Arapaho rock glacier is an example of a tongue-shaped rock glacier. Spatulate rock glaciers develop when the front section of a tongue-shaped rock glacier spreads laterally. Examples of this type are not present within the area of this investigation.

Potter (1972) further defined rock glaciers based on the type of ice contained. Rock glaciers that contain considerable rock debris cemented by interstitial ice are ice-cemented rock glaciers, and rock glaciers composed of relatively clean glacier ice mantled by debris are ice-cored rock glaciers.

PAST WORK ON ROCK GLACIERS

Several ideas have been proposed for the origin and movement of rock glaciers. Spencer (1900) refers to rock glaciers as a "peculiar form of talus." Rohn (1900) describes rock glaciers as "talus slopes that flow." Cross and Howe (1905) call them rock streams, and consider them to be unusual types of moraines. Howe (1909), from observations in the San Juan Mountains, states that rock glaciers are the result of landslides that deposited rock debris on the surfaces of small glaciers during the waning stages of the last ice age. Capps (1910) proposes that water froze around debris that had accumulated at the base of the cirque headwall and melting and freezing of the interstitial ice caused movement of the rock glacier. Chaix (1923) maintains that movement of rock glaciers is due to interstitial mud and clay which lubricates the debris. Brown (1925) describes a mining tunnel constructed through a rock glacier in the San Juan Mountains, Colorado in which the first few feet of the tunnel penetrated loose rock debris, the next 300 feet consisted of ice cemented debris, and the last 100 feet encountered clean ice. Ives (1940) refers to one rock glacier in the Colorado Front Range as a "runaway" terminal moraine and states that movement is caused by thrusting in the interstitial ice. Richmond (1952) proposes that rock glaciers once contained an ice core and that the ridges and furrows were caused by advances and retreats of the ice beneath the debris. Wahrhaftig and Cox (1959) state that rock glaciers are masses of debris and interstitial ice and that they owe their movement to the flow of the interstitial ice.

THE ARAPAHO ROCK GLACIER

Outcalt and Benedict (1965) photographed small exposures of glacier ice beneath the upvalley portion of Arapaho rock glacier in the Colorado Front Range. On August 22, 1966, Wallace (1967) discovered that a meltwater stream flowing over the upvalley one-third of Arapaho rock glacier had carved a channel approximately 40 feet deep into an ice glacier lying beneath a thin cover of rock debris. Shear planes exposed along this

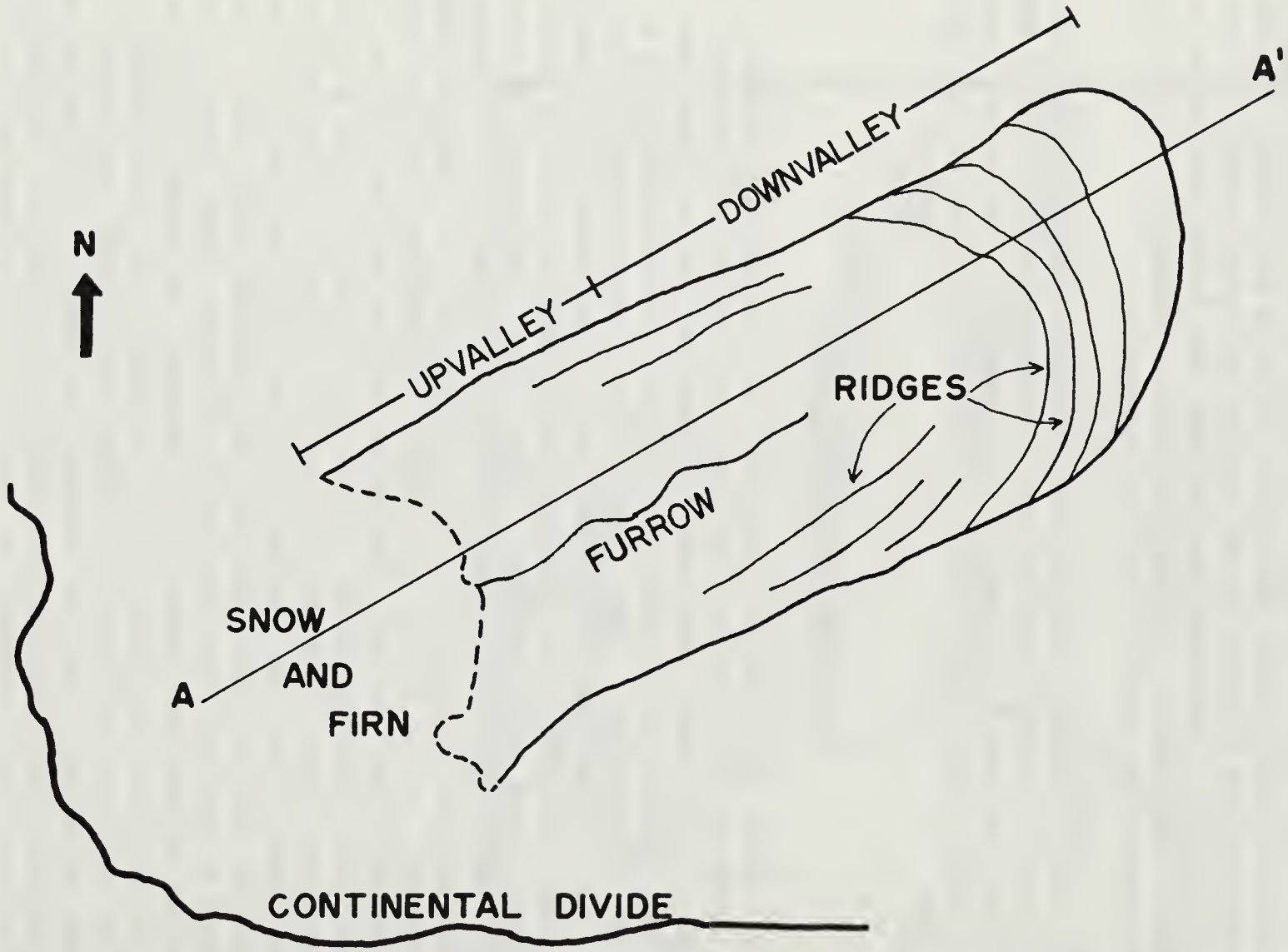

FIG. 2 PLAN VIEW OF ARAPAHO ROCK GLACIER

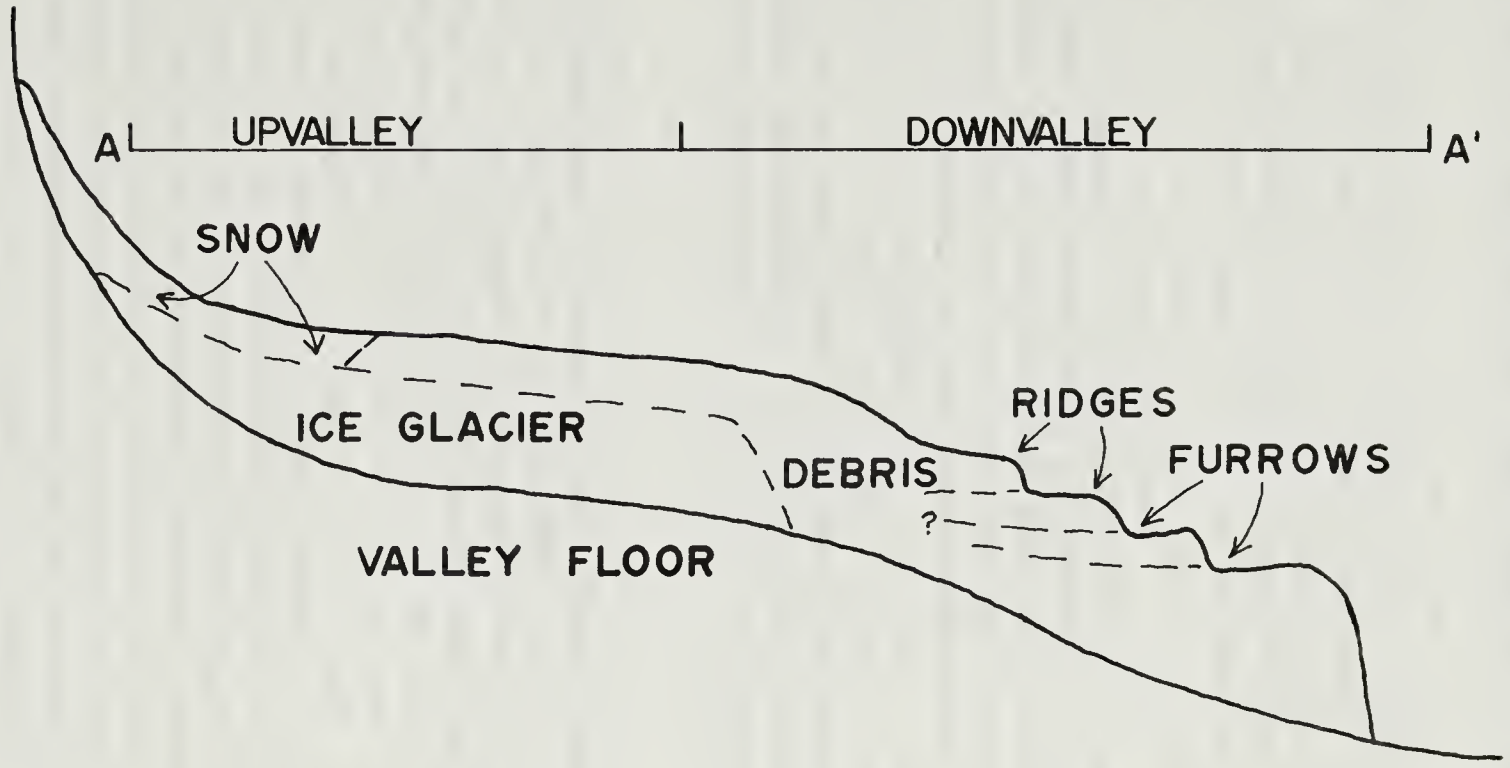

FIG. 3 LONGITUDINAL CROSS SECTION OF ARAPAHO ROCK GLACIER.

channel yielded pollen, plant and insect remains which were dated radiometrically at 1000 ± 90 years B.P., the Audubon Stage of Neoglaciation (Mahaney, 1972; Benedict, 1973 [a], [b]). White (1971, 1975, 1976) made numerous contributions to the origin of rock glaciers and compiled data concerning rates of movement of rock glaciers in the Colorado Front Range. White recognized the importance of creep of glacier ice and of interstitial ice as a possible mechanism of origin and movement for Arapaho rock glacier. Potter (1972) also recognized glacier ice and interstitial ice in the Galena Creek rock glacier in the Absaroka Mountains, Wyoming.

Description--Arapaho rock glacier is tongue-shaped, approximately 825 feet wide, 2,000 feet long, and 70 to 90 feet thick. The average slope of the front edge of the rock glacier is 46°, that of the sides is about 39°, and the upper surface slopes 16° downvalley (Wallace, 1967). Diagnostic relief features exist on the upper surface of the rock glacier, the most prominent being sets of nearly parallel transverse ridges and furrows (Figs. 2 and 3). Wahrhaftig and Cox (1959) describe such transverse ridges on Alaskan rock glaciers as rounded and the furrows between as V-shaped. This is also true of some Colorado rock glaciers, especially those observed in the San Juan Mountains. However, cross profiles of the ridges and furrows of the Arapaho rock glacier are, in most cases, asymmetrical with the steep portion of the ridges facing outward toward the sides and front (Fig. 3). Heights of the ridges, measured from furrow bottoms to ridge tops, range from 12 to 20 feet (Wallace, 1967). The top surface of some ridges is tilted and slopes backward toward the rock glacier head (Fig. 3). Longitudinal ridges are parallel to the sides for short distances and then curve toward the center to form transverse ridges (Fig. 2).

The upvalley one-third of Arapaho rock glacier has an ice core whereas the downvalley two-thirds consists of rock debris cemented by interstitial ice. The rock debris ranges from clay- and silt-size particles to boulders 25 feet in diameter. Mechanical analyses of the finer material collected from the front of the rock glacier indicate 40 percent sand and 5 percent silt and clay for particles less than 4mm (Wallace, 1967). Similar analyses by White (1971) yield 68 percent sand and 9 percent silt and clay. The debris is angular to subangular, and none is faceted or striated. At first glance the glacier front and ridge appear to be layered, with coarse debris dominant at the top and fine dominant at the bottom. But closer inspection reveals the bottom layer has just as much coarse material as the top; the interstices are filled with finer debris of similar color so that, at first glance, all of the material appears fine grained. It is my opinion that this is caused by a downward sifting of the finer debris during movement. White (1971) calculates the volume of debris in Arapaho rock glacier to be about 1,034,900m^3.

Another striking surface feature is a meandering incised furrow (mentioned above) which extends longitudinally down the center of the upvalley portion of the rock glacier (Fig. 2). I believe that a collapse feature which formed when a meltwater stream cut a channel into the underlying ice glacier, allowed the surface debris to slump into this channel and create a furrow.

Wahrhaftig and Cox (1959) describe "the head" as the place where a rock glacier merges with an ice glacier, or where it ends abruptly at a pit formerly occupied by a glacier. The head of Arapaho rock glacier ends in a shallow depression, the bottom of which is occupied by an ice glacier buried by talus and rockfall debris mostly derived from the cirque headwall.

Smaller less conspicuous surface features include pits and conical hills. The pits, usually only a few feet deep and irregular in outline, are probable collapse features caused by irregular melting of underlying glacier or interstitial ice. The hills are more difficult to explain. Some are almost perfectly conical in shape, rise 10-12 feet in height, and have a basal diameter of 10-15 feet (Wallace, 1967). I have no other explanation as to the origin of the conical hills except that they may have been formed by differential pressures exerted during the advance or readvances of the rock glacier, and later collapse of surrounding rock glacier material.

Questions Concerning Cause of Movement--There are three major questions concerning the cause of movement of Arapaho rock glacier: a) Can movement be due to creep of interstitial ice? b) Can creep of the ice glacier buried beneath the upvalley one-third of the rock glacier cause the movement? c) Can movement be due to a combination of creep of interstitial ice and the buried ice glacier?

Questions Concerning Origin of Rock Debris--There are three major questions concerning the origin of the rock debris in Arapaho rock glacier: a) Is the debris morainal in origin? b) Is the debris a result of talus accumulation from the very large cirque headwall at the head of the rock glacier? c) Is the rock debris a combination of talus and moraine?

Evidence of Movement—A number of features associated with the Arapaho rock glacier suggest that it has moved in the past. The most conclusive is the pattern of longitudinal and transverse ridges and furrows (Figs. 2 and 3). In plan view these features suggest the rock glacier behaved as a viscous fluid. That is, ridges are similar in appearance to the transverse flow ridges of lava.

Numerous other features suggest that movement is presently taking place. (1) The steep slope (averaging 40° and varying from 36° to 47°) of the front of the rock glacier and the fronts of the longitudinal and transverse ridges indicate that movement has been recent in order to maintain such a high angle of repose (Wallace, 1967). Angles of the upper portion of the fronts are always greater, suggesting that the top portion of any lobe moves faster than the bottom. (2) The fronts of the rock glacier and of the ridges are unstable and are difficult to walk on. Large blocks were observed rolling from the fronts. Small mudflows are common along the fronts especially after light rains. From this visible evidence of mass movement, it is apparent that Arapaho rock glacier must be moving in order for the steep fronts to be maintained. (3) Fronts of the rock glacier and ridges appear as fresh surfaces because lichen and other plants seldom grow there. The fronts are not stable enough for vegetation to become established. (4) A number of rock glaciers along the Colorado Front Range were surveyed (plane table and alidade) over a

five year period (Wallace, 1967; White, 1971). White (1971) determined that the average annual movement was 9.7 cm for Fair rock glacier (Fig. 1), 6.6 cm for Taylor rock glacier (front of Taylor glacier, Rocky Mountain National Park) and 5.0 cm for Arapaho rock glacier.

Origin of Movement and Rock Debris--Based on the knowledge that an ice glacier or relic ice glacier is beneath the upper part of the Arapaho rock glacier, I conclude that the origin of movement of the rock glacier is, in part, due to creep of this buried glacier. The underlying glacier probably caused past movement, is maybe responsible for producing part of the present shape and surface features as well as being an important factor in causing some of the present movement. However, the importance of interstitial ice must not be minimized because the downvalley two-thirds of the Arapaho rock glacier contains interstitial ice only and does not possess a glacial core. Thus, the interstitial ice must play a role in maintaining the steep front and sides of the entire rock glacier. The interstitial ice also must be important in accommodating movement caused either by the creep of the upvalley ice glacier and/or by the effects of gravity on the rock debris and interstitial ice. Thus, I conclude that creep of both interstitial ice and a buried ice glacier are probably responsible for the movement of the Arapaho rock glacier. However, were the ice glacier not present the interstitial ice alone would be enough to permit movement.

It is difficult to determine the source of the rock debris in the Arapaho rock glacier. I cannot say with certainty whether the rock debris is derived from glacial plucking or as talus from the cirque headwall by the effect of freezing and thawing. I favor talus accumulation as the major source based on four facts: (1) Much of the debris would be too large to have been plucked from the cirque floor and then transported along shear planes to accumulate on the top and at the front of the ice glacier. One or two blocks are nearly 25 feet in diameter while many others are 10 to 15 feet. These blocks are considered too large to have been eroded and deposited by such a small ice glacier. (2) The debris is all very angular even at the front of the rock glacier. Glacial transportation, even for a distance of about 900 feet, should produce some abrasion of corners and edges. (3) The volume of debris (1,034,900 m^3, White, 1971) is much too large to have been supplied by such a small ice glacier. (4) The cirque headwall, rising approximately 1,237 feet above Arapaho rock glacier, provides a source area large enough to supply the debris. Freezing and thawing of water in cracks on this jointed headwall could supply sufficient rock debris. I therefore conclude that only a small part of the total amount of rock debris is of glacial origin and it is no longer distinguishable since it is dispersed throughout the rock glacier.

It is my opinion that the origin of Arapaho rock glacier is due to the formation of interstitial ice in talus that accumulated at the front of the presently buried ice glacier. The bulk of this debris in the rock glacier was transported as rockfall, from the headwall, onto and across the ice glacier thus burying it. After accumulation of a sufficient amount of talus and possibly some morainal material, and the formation of interstitial ice, Arapaho rock glacier developed. The force of gravity caused accumulation of rock debris and interstitial ice to flow in a

manner similar to an ice glacier thus creating the present shape and surface features of the rock glacier. Creep of the upvalley buried ice glacier may aid in the movement.

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CATALOGUE OF THE VASCULAR PLANTS OF THE WESTERN ILLINOIS UNIVERSITY ALICE L. KIBBE LIFE SCIENCE STATION AND VICINITY

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ABSTRACT

Floristic studies conducted primarily from 1964 to the present at Western Illinois University's Alice L. Kibbe Life Science Station and environs have resulted in a total of 683 species of vascular plants.

The Alice L. Kibbe Life Science Station was established in 1964 as an instructional and research facility of Western Illinois University. It consists of 215 acres located at the north edge of Warsaw, Hancock County, Illinois. Adjacent to the station the Nature Conservancy owns 464 acres which provide a sanctuary for a wintering population of bald eagles. These 679 acres comprise the principal area included in this catalogue of vascular plants.

The area is located on the Mississippi River limestone bluffs which are covered with upland timber soils primarily derived from loess and glacial soils from the Upper Illinois glaciation. Schwegman (1973) designates this area as the glaciated section of the middle Mississippi Border Division in the classification of the Natural Divisions of Illinois. A number of rapidly descending valleys of various sizes with gentle to rather steep-sided slopes are characteristic. The floors of the larger valleys (glens) are occupied by intermittent streams which generally carry a small volume of water during the time of heavy rainfall in spring and fall and are dry during the summer. There are no permanent streams present. Rock outcrops are present along the sides of some of the larger valleys such as Prairie Glen, Spring Glen and, most notable and spectacular, Cedar Glen. Between these three major glens on the ridge-tops are old fields which were formerly cultivated. On the ridge between Prairie and Spring Glens the old field has been converted to a 20-acre artificial prairie of which 8 acres were seeded in 1969 and 12 acres in 1972. Both were seeded with Andropogon furcatus Muhl., A. scoparius Michx., Sorghastrum nutans (L.) Nash., and Panicum virgatum L. Today S. nutans and P. virgatum dominate the 12 acres and S. nutans dominates the 8 acres and in each there are only a few forbes. Below the bluffs are the bottomlands including the flood plain of the Mississippi River.

The area was originally forested but has been disturbed by past practices of farming, logging, grazing and fire. The steeper slopes are the least disturbed areas and perhaps some of them have had minimal to no

disturbance. Since there have been no recent major disturbances the present forest is developing well.

Eight general plant communities can be distinguished: upland forest, bluff and slope, prairie, bottomland, aquatic, old field, lawn, and railroad, the latter three being disturbance communities. The drier uplands support an oak-hickory forest with the major species being Quercus alba L., Q. velutina Lam., Q. macrocarpa Michx., Q. rubra L., Q. imbricaria Michx. and Carya ovata (Mill.) K. Koch. Major woody plants of the mesic slopes are Carya cordiformis (Wang.) K. Koch, Celtis occidentalis L., Juglans nigra L., Acer saccharum Marsh., and Tilia americana L. in the overstory and Aesculus glabra Willd., Cercis canadensis L., Cornus drummondi C.A. Mey., Ostrya virginiana (Mill.) Koch and Staphylea trifoliata L. common in the understory. Plants characteristic of the herbaceous layer include Mertensia virginica (L.) Pers., Hepatica acutiloba DC., Claytonia virginica L., Podophyllum peltatum L., Polygonatum commutatum (Schultes) Dietr., Sanguinaria canadensis L., Aster sp., Solidago sp. and associated woodland plants. Amelanchier arborea (Michx. f.) Fern., Juniperus virginiana L., Quercus muhlenbergii Engelm. and Aquilegia canadensis L. are found particularly on the steeper rocky slopes. A thriving colony of Camptosorus rhizophyllus (L.) Link occurs on "Hanging Bridge" in Cedar Glen.

There are several natural small hill-type prairies usually dominated by Andropogon scoparius on the top of and sometimes extending back from the glen walls where, due to exposure, wind, shallow soil, and good drainage, the conditions are relatively dry. Some other characteristic plants are Lithospermum canescens (Michx.) Lehm., Amorpha canescens Pursh, Petalostemum purpureum (Vent.) Rydb., Psoralea onobrychis Nutt. and Sorghastrum nutans (L.) Nash. Various xeric-type lichens and mosses can usually be seen also. It is commonly found that most of these areas are being invaded by woody plants such as Cornus sp. and Crataegus sp.

There are three major old field communities present. One, of 20 acres on the ridge between Spring and Prairie Glens belonging to the Kibbe Station has been converted to an artificial prairie as noted earlier. On the ridge between Cedar and Prairie Glens belonging to the Nature Conservancy is a 45 acre old field of which the southern-most 28 acres have been uncultivated since 1973 and the northern-most 17 acres uncultivated since 1971. The herbaceous cover consists of various species of Ambrosia, Solidago, Erigeron, Amaranthus, Bromus, Aster, Cirsium, Setaria and other such characteristic plants. Some species of woody plants as Rubus, Crataegus, Cornus, and Quercus are beginning to become established. The 17 acre old field belonging to the Nature Conservancy is located below the bluffs on the floodplain and has been uncultivated since 1970. Due to this location which results in it being subject to yearly flooding the characteristic plants are in marked contrast to the upland old field. Such plants include species of Xanthium, Polygonum, Cuscuta and Setaria. Salix has started to invade this old field.

The bottomland community subject to flooding every spring and to a lesser extent in the fall occurs between the bluffs and the Mississippi River as well as on the islands in the river. A cathedral forest of tall mature Populus deltoides Marsh. and Acer saccharinum L. is present along the edge of the river. This forest is practically devoid of any understory or herbaceous vegetation. The islands, as well as other areas of the

mainland floodplain, have a dense herbaceous cover as well as vines as Vitis sp., Menispermum canadense L., Ampelopsis cordata Michx. and Rhus radicans L. amid the varying aged forest of Salix interior Rowlee, S. nigra Marsh., Populus deltoides Marsh., Acer saccharinum L., Ulmus rubra Muhl., Celtis occidentalis L. and Acer negundo L. Platanus occidentalis L. and Fraxinus americana L. are more characteristically found on the margins of the larger intermittent streams rather than on the river floodplain. On the islands and floodplain characteristic herbaceous plants as Laportea canadensis (L.) Gaud., Boehmeria cylindrica (L.) Sw., Pilea pumila (L.) A. Gray and Sicyos angulatus L. are present.

The true aquatic habitats are the Mississippi River and its sloughs which permeate the floodplain and islands to varying degrees, as well as the pond which was constructed above the bluffs in 1966 as a water supply for the station. Only Lemma minor L. and Ceratophyllum demersum L. have been found in the river. In the pond, L. Minor and Potamogeton foliosus Raf. are present. At the edge of the pond and in the drainage ditch to the pond where the soil is wet can be found such herbaceous plants as Cyperus sp., Scirpus sp., Typha latifolia L. and Carex sp. and woody willows. In the wet area at the mouth of the spring in Spring Glen can be found a dense stand of Equisetum. A shoreline plant association on sandy or muddy soils characteristic of outwashes, spits and sandbars, includes Rorippa sp., Acnida altissima Riddell, Bidens sp., Artemisia annua L., Eclipta alba (L.) Hassk., Lycopus sp., Ammannia sp., Polygonum sp., Gratiola neglecta Torr., Glyceria sp., and Eragrostis hypnoides (Lam.) BSP.

The lawn community is found around the buildings and consists of the lawn and ornamental plantings. Characteristic plants include Poa pratensis L., Digitaria sanguinalis (L.) Scop., Taraxacum officinale Wiggers, Plantago lanceolata L., P. rugelii Dcne., Glecoma hederacea L., Stellaria media (L.) Vill., Viburnum lantana L., Syringa vulgaris L., Ligustrum vulgare L., Belamcanda chinensis (L.) DC., Iris germanica L., and Metasequoia glyptostroboides Hu & Cheng.

The cinder ballast roadbed of the recently abandoned railroad line which transverses the edge of the area is a dry, well drained, often unstable substrate which supports some representative plants as Chaenorrhinum minus (L.) Lange, Silene antirrhina L., Poa compressa L. Verbascum thapsus L. and Polanisia dodecandra (L.) DC.

Previous work concerning the flora of this area are those of Kibbe (1952), Kunshek (1971) and Wells (1977). Kibbe in her botanical survey of Hancock County frequently mentions Cedar Glen plants as well as information on the climate, geology, soils and past and present vegetation of this part of the county. Kunshek studied and compared the species composition and successional patterns of the vegetation of the floodplains of the Kibbe Station mainland and a nearby island. Wells studied the present vegetational patterns and successional trends on Eagle (Mink) Island which belongs to the Nature Conservancy. Currently other studies concerning the vegetation and ecology of both lowlands and uplands are in progress.

This catalogue, which can serve as a checklist, includes all of the vascular plants of the designated area which have been collected to date and are verified by herbarium specimen deposited in the herbarium of the A. L. Kibbe Life Science Station (WARK) with the one exception that certain species

cited by Kibbe (1952) and followed by an X in this catalogue do not have voucher specimens. An asterisk (*) following the species name indicates it to be an alien (i.e. not native to Illinois) according to Myers (1972). A cross-hatch (#) indicates that it has been planted, usually as an ornamental. There are, however, six species that occur both as planted and unplanted; these are not followed by a cross-hatch: Maclura pomifera (Raf.) Schneid. which was planted in the past as hedge-rows and now are large old trees, Robinia pseudoacacia L. planted in the past as ground cover, and the four prairie grass species mentioned earlier planted to establish the artificial prairie. Vascular plants observed but which could not be determined to species are not included as for example Sagittaria which is present but has not been observed to form fruits which are needed for certain identification.

A total of 683 species distributed in 371 genera and 109 families (1 arthrophyte, 2 fern, 4 gymnosperm, 89 dicot and 13 monocot) are listed. Of these species 164 (24.0%) are aliens and 40 (5.9%) are planted. Nomenclature follows that of Jones (1963) and, for ornamental plants, of Bailey (1949).

DIVISION ARTHROPHYTA

EQUISETACEAE

Equisetum arvense L.
E. hyemale L.
E. laevigatum A. Br.

DIVISION PTEROPHYTA

OPHIOGLOSSACEAE

Botrychium virginianum (L.) Sw.

POLYPODIACEAE

Adiantum pedatum L.
Asplenium platyneuron (L.) Oakes
Camptosorus rhizophyllus (L.) Link
Cystopteris bulbifera (L.) Bernh. X
C. fragilis (L.) Bernh.
Polystichum acrosticoides (Michx.) Schott
Woodsia obtusa (Spreng.) Torr.

DIVISION CONIFEROPHYTA

CUPRESSACEAE

Juniperus virginiana L.

PINACEAE

Pinus strobus L. #
Tsuga canadensis Carr. #*

TAXACEAE

Taxus baccata L. #*

TAXODIACEAE

Metasequoia glyptostroboides #* Hu & Cheng
Taxodium distichum (L.) Rich. #

DIVISION ANTHOPHYTA

Class Dicotyledoneae

ACANTHACEAE

Ruellia humilis Nutt.
R. pedunculata Torr.
R. strepens L.

ACERACEAE

Acer negundo L.
A. nigrum Michx. f.
A. palmatum Thunb. #*
A. saccharinum L.
A. saccharum Marsh.

AIZOACEAE

Mollugo verticillata L. *

AMARANTHACEAE

Acnida altissima Riddell
Amaranthus hybridus L. X*
A. retroflexus L. *
A. spinosus L. *

ANACARDIACEAE

Rhus aromatica Ait.
R. glabra L.
R. radicans L.

ANNONACEAE

Asimina triloba (L.) Dunal

APOCYNACEAE

Apocynum androsaemifolium L.
A. cannabinum L.
A. sibiricum Jacq.
Vinca minor L. *

ARALIACEAE

Aralia racemosa L.
Panax quinquefolius L.

ARISTOLOCHIACEAE

Asarum reflexum Bickn.

ASCLEPIADACEAE

Ampelamus albidus (Nutt.) Britt.
Asclepias hirtella (Pennell) Woodson
A. incarnata L.
A. purpurascens L.
A. quadrifolia Jacq.
A. syriaca L.
A. tuberosa L.
A. verticillata L.

BALSAMINACEAE

Impatiens biflora Walt.
I. pallida Nutt.

BERBERIDACEAE

Berberis thunbergii DC. *

BETULACEAE

Betula nigra L.
Carpinus caroliniana Walt.
Corylus americana Walt.
Ostrya virginiana (Mill.) Koch

BIGNONIACEAE

Campsis radicans (L.) Seem.
Catalpa bignonioides Walt. *

BORAGINACEAE

Cynoglossum officinale L. X*
Hackelia virginiana (L.) I. M. Johnst.
Lithospermum canescens (Michx.) Lehm.
Mertensia virginica (L.) Pers.
Myosotis virginica (L.) BSP.
Onosmodium hispidissimum Mack.

CAMPANULACEAE

Campanula americana L.
Specularia perfoliata (L.) * A. DC.

CANNABINACEAE

Humulus americanus Nutt.

CAPPARIDACEAE

Cleome spinosa L. #*
Polanisia dodecandra (L.) DC.

CAPRIFOLIACEAE

Lonicera bella Zabel #*
L. prolifera (Kirchn.) Rehd.
L. xylosteum L. #*
Sambucus canadensis L.
Symphoricarpos orbiculatus Moench
Triosteum aurantiacum Bickn.
T. perfoliatum L.
Viburnum lantana L. #*
V. opulus L. #*
V. prunifolium L.
V. rafinesquianum Schultes
V. recognitum Fern.
V. trilobum Marsh. #

CARYOPHYLLACEAE

Cerastium nutans Raf.
C. vulgatum L. *
Dianthus armeria L. *
Lychnis alba Mill. *
Saponaria officinalis L. *
Silene antirrhina L.
S. noctiflora L. *
S. stellata (L.) Ait. f.
S. virginica L.
Stellaria media (L.) Vill. *

CELASTRACEAE

Celastrus scandens L.
Euonymus alatus Sieb. #*
E. atropurpureus Jacq.

CERATOPHYLLACEAE

Ceratophyllum demersum L.

CHENOPODIACEAE

Chenopodium album L. *
C. ambrosioides L. *
C. boscianum Moq.
C. hybridum L. *
C. pratericola Rydb. *

CISTACEAE

Lechea tenuifolia Michx.

COMPOSITAE

Achillea millefolium L. *
Ambrosia artemesiifolia L.
A. trifida L.
Antennaria neglecta Greene
A. plantaginifolia (L.) Hook.
Anthemis cotula L. *
Arctium minus (Hill) Bernh. *
Artemisia annua L. *
Aster azureus Lindl.
A. cordifolius L.
A. drummondii Lindl.
A. exiguus (Fern.) Rydb.
A. laevis L.
A. lateriflorus (L.) Britt.
A. novae-angliae L.
A. oblongifolius Nutt.
A. ontarionis Wieg.
A. pilosus Willd.
A. praealtus Poir. X
A. sagittifolius Wedem.
A. simplex Willd.
A. turbinellus Lindl.
Bidens aristosa (Michx.) Britt.
B. bipinnata L.
B. cernua L.
B. comosa (Gray) Wieg.
B. frondosa L.
B. polylepis Blake
B. vulgata Greene
Cacalia atriplicifolia L. X

C. muhlenbergii (Sch.-Bip.) Fern. X
Chrysanthemum leucanthemum L. *
Cichorium intybus L. *
Cirsium altissimum (L.) Spreng.
C. discolor (Muhl.) Spreng.
C. vulgare (Savi) Tenore *
Coreopsis palmata Nutt.
Echinacea pallida Nutt.
E. purpurea (L.) Moench
Eclipta alba (L.) Hassk.
Erechtites hierac ifolia (L.) Raf.
Erigeron annuus (L.) Pers.
E. canadensis L.
E. divaricatus Michx.
E. philadelphicus L.
E. strigosus Muhl.
Eupatorium altissimum L.
E. perfoliatum L.
E. purpureum L.
E. rugosum Houtt.
E. serotinum Michx.
Galinsoga ciliata (Raf.) Blake *
Gnaphalium obtusifolium L.
Grindelia squarrosa (Pursh) Dunal *
Helenium autumnale L.
Helianthus annuus L. *
H. grosseserratus Martens
H. hirsutus Raf.
H. strumosus L.
H. tomentosus Michx.
Heliopsis helianthoides (L.) Sweet
Hieracium scabrum Michx.
Iva ciliata Willd.
Krigia biflora (Walt.) Blake
Kuhnia eupatorioides L.
Lactuca canadensis L.
L. floridana (L.) Gaertn.
L. scariola L. *
Liatris aspera Michx.
L. cylindracea Michx.
Matricaria matricarioides (Less.) Porter *
Parthenium integrifolium L.
Polymnia canadensis L.
Prenanthes alba L.
Ratibida pinnata (Went.) Barnh.
Rudbeckia hirta L.
R. subtomentosa Pursh
R. triloba L.
Senecio pauperculus Michx.
S. plattensis Nutt.
Silphium integrifolium Michx.
S. laciniatum L.
S. perfoliatum L.
Solidago altissima L.
S. gigantea Ait.
S. glaberrima Martens
S. juncea Ait.
S. latifolia L.
S. nemoralis Ait.
S. rigida L.
S. ulmifolia Nutt.
Sonchus oleraceus L. *
Taraxacum erythrospermum Andrs. *
T. officinale Wiggers *
Verbesina alternifolia (L.) Britt.
Vernonia missurica Raf.
Xanthium chinense Mill.
X. commune Britt.

CONVOLVULACEAE

Convolvulus americanus (Sims.) Greene
Cuscuta gronovii Willd.
Ipomaea hederacea Jacq. *
I. pandurata (L.) G. F. W. Mey.

CORNACEAE

Cornus drummondi C. A. Mey.
C. obliqua Raf.

CRASSULACEAE

Sedum sarmentosum Bunge *
S. triphyllum (Haw.) S. F. Gray *

CRUCIFERAE

Arabis canadensis L.
A. laevigata (Muhl.) Poir.
A. pycnocarpa Hopkins
A. shortii (Fern.) Gleason
Armoracia rusticana (L.) Gaertn. *
Barbarea vulgaris R. Br. *
Capsella bursa-pastoris (L.) * Medic
Cardamine pensylvanica Muhl.
Dentaria lacinata Muhl.
Descurainia brachycarpa (Richards) O. E. Schulz
Draba reptans (Lam.) Fern.
Lepidium campestre (L.) R. Br. *
L. densiflorum Schrad. *
L. virginicum L.
Rorippa islandica (Oeder) Borbas
R. sessiflora (Nutt.) Hitchc.
Sisymbrium officinale (L.) Scop. *
Thlaspi arvense L. *

CUCURBITACEAE

Sicyos angulatus L.

ELAEAGNACEAE

Elaeagnus angustifolia L. *
E. umbellata Thunb. #*
Shepherdia argenta Nutt. #*
S. canadensis (L.) Nutt. #

ERICACEAE

Monotropa uniflora L.

EUPHORBIACEAE

Acalypha rhomboidea Raf.
A. virginica L.
Chamaesyce maculata (L.) Small
C. supina (Raf.) Moldenke
Croton glandulosus L. *
Euphorbia corollata L.
Poinsettia dentata (Michx.) Small *

FAGACEAE

Castanea mollissima Blume #*
Quercus alba L.
Q. bicolor Willd.
Q. imbricaria Michx.
Q. macrocarpa Michx.
Q. marilandica Muenchh.
Q. muhlenbergii Engelm.
Q. rubra L.
Q. stellata Wang.
Q. velutina Lam.

FUMARIACEAE

Corydalis flavula (Raf.) DC.
Dicentra canadensis (Goldie) Walp.
D. culcullaria (L.) Bernh.

GENTIANACEAE

Sabatia angularis (L.) Pursh

GERANIACEAE

Geranium carolinianum L.
G. maculatum L.

GROSSULARIACEAE

Ribes missouriense Nutt.

HIPPOCASTANACEAE

Aesculus glabra Willd.
A. octandra Marsh. #*

HYDRANGEACEAE

Hydrangea paniculata Sieb. #*
Philadelphicus inodorus L. #*
P. pubescens Loisel. #

HYDROPHYLLACEAE

Ellisia nyctelea L.
Hydrophyllum appendiculatum Michx.
H. virginianum L.

HYPERICACEAE

Hypericum perforatum L. *
H. punctatum Lam.
H. sphaerocarpum Michx.

ILLECEBRACEAE

Paronychia canadensis (L.) Wood.
P. fastigata (Raf.) Fern.

JUGLANDACEAE

Carya cordiformis (Wang.) K. Koch
C. ovata (Mill.) K. Koch
C. tomentosa (Poir.) Nutt.
Juglans nigra L.

LABIATAE

Agastache nepetoides (L.) Ktze.
Blephilia ciliata (L.) Benth.
Glecoma hederacea L. *
Hedeoma hispida Pursh
H. pulegioides (L.) Pers.
Isanthus brachiatus (L.) BSP.
Leonurus cardiaca L. *
Lycopus americanus Muhl.
L. virginicus L.
Mentha canadensis L. X (as M. arvensis var. glabrata (Benth.) Fernald)
Monarda fistulosa L.
Nepeta cataria L. *
Prunella vulgaris L. *
Pycnanthemum pilosum Nutt.
P. virginianum (L.) Dur. & Jacks.
Scutellaria lateriflora L.
S. ovata Hill
S. parvula Michx.
Stachys hispida Pursh
S. tenuifolia Willd.
Teucrium canadense L.

LAURACEAE

Sassafras albidum (Nutt.) Nees

LEGUMINOSAE

Amorpha canescens Pursh
A. fruticosa L.
Amphicarpa comosa (L.) G. Don
Apios americana Medic.
Baptisia leucantha T. & G.
B. leucophaea Nutt.
Cassia fasciculata Michx.
C. marilandica L.
Cercis canadensis L.
Coronilla varia L. #*
Desmodium canescens (L.) DC. X
D. cuspidatum (Muhl.) Loud. X
D. glabellum (Michx.) DC.
D. glutinosum (Muhl.) Wood
D. longifolium (T. & G.) Smyth
D. nudiflorum (L.) DC.
D. paniculatum (L.) DC.
D. rigidum (Ell.) DC.
D. sessifolium (Torr.) T. & G.
Gleditsia triacanthos L.
Glycine max (L.) Merr. *
Gymnocladus dioica (L.) K. Koch
Lespedeza capitata Michx.
L. stipulacea Maxim. *
L. violacea (L.) Pers.
L. virginica (L.) Britt.
Medicago lupulina L. *
M. sativa L. *
Melilotus alba Desr. *

M. officinalis (L.) Lam. *
Petalostemum candidum (Willd.) Michx.
P. purpureum (Vent.) Rydb.
Psoralea onobrychis Nutt.
P. tenuiflora Pursh
Robinia pseudoacacia L.
Sophora japonica L. #*
Strophostyles helvola (L.) Britt.
S. leiosperma (T. & G.) Piper
Tephrosia virginiana (L.) Pers.
Trifolium hybridum L. *
T. pratense L. *
T. procumbens L. *
T. repens L. *

LINACEAE

Linum sulcatum Riddell

LOBELIACEAE

Lobelia inflata L.
L. siphilitica L.
L. spicata Lam.

LYTHRACEAE

Ammannia auriculata Willd.
A. coccinea Rottb.
Cuphea petiolata (L.) Koehne
Rotala ramosior (L.) Koehne

MAGNOLIACEAE

Magnolia soulangeana Soul. #*
M. stellata Maxim. #*

MALVACEAE

Abutilon theophrasti Medic. *
Althaea rosea (L.) Cav. #*
Hibiscus trionum L. *
Malva neglecta Wallr. *
Sida spinosa L. *

MENISPERMACEAE

Menispermum canadense L.

MORACEAE

Maclura pomifera (Raf.) Schneid. *
Morus alba L. *
M. rubra L.
M. tatarica L. *

NYCTAGINACEAE

Mirabilis nyctaginea (Michx.) MacM.

OLEACEAE

Forsythia viridissima Lindl. #*
Fraxinus americana L.
F. lanceolata Borkh.
F. nigra Marsh.
F. pennsylvanica Marsh.
F. quadrangulata Michx.
Ligustrum vulgare L. #*
Syringa vulgaris L. #*

ONAGRACEAE

Circaea latifolia Hill
Oenothera biennis L.
O. laciniata Hill

OXALIDACEAE

Oxalis dillenii Jacq.
O. stricta L.
O. violacea L.

PAPAVERACEAE

Sanguinaria canadensis L.

PENTHORACEAE

Penthorum sedoides L.

PHRYMACEAE

Phryma leptostachya L.

PHYTOLACCACEAE

Phytolacca americana L.

PLANTAGINACEAE

Plantago artistata Michx.
P. lanceolata L. *
P. rugelii Dcne.
P. virginica L.

PLATANACEAE

Platanus occidentalis L.

PODOPHYLLACEAE

Caulophyllum thalictroides (L.) Michx. X
Podophyllum peltatum L.

POLEMONIACEAE

Phlox divaricata L.
P. paniculata L.
Polemonium reptans L.

POLYGALACEAE

Polygala sanguinea L.
P. senega L.
P. verticillata L.

POLYGONACEAE

Fagopyrum esculentum Moench *
Polygonum aviculare L. *
P. convolvulus L. *
P. erectum L.
P. lapathifolium L. *
P. pensylvanicum L.
P. persicaria L. *
P. punctatum Ell.
P. scandens L.
P. virginianum L.
Rumex acetosella L. *
R. altissimus Wood
R. crispus L. *
R. triangulivalvis (Danser) Rech. f.
R. verticillatus L.

PORTULACACEAE

Claytonia virginica L.
Portulaca oleracea L. *

PRIMULACEAE

Androsace occidentalis Pursh
Lysimachia ciliata L.

RANUNCULACEAE

Actaea alba (L.) Mill.
Anemone canadensis L.
A. cylindrica Gray

A. virginiana L.
Anemonella thalictroides (L.) Spach
Aquilegia canadensis L.
Clematis pitcheri T. & G.
C. virginiana L.
Delphinium carolinianum Walt.
Hepatica acutiloba DC.
Isopyrum biternatum (Raf.) Torr.
Ranunculus abortivus L.
R. septentrionalis Poir.
Thalictrum dasycarpum Fisch. & Lall.

RHAMNACEAE

Ceanothus americanus L.
Rhamnus cathartica L. *
R. lanceolata Pursh

ROSACEAE

Agrimonia parviflora Ait.
A. pubescens Wallr.
Amelanchier arborea (Michx. f.) Fern.
Aruncus dioicus (Walt.) Fern.
Chaenomeles lagenaria Koidz. #*
Cotoneaster dielsiana Pritz. #*
C. divaricata Rehd. & Wils. #*
Crataegus crusgalli L.
C. mollis (T. & G.) Scheele
Fragaria chiloensis x virginiana Duch.
F. virginiana Duch.
Geum canadense Jacq.
Malus ioensis (Wood) Britt.
M. pumila Mill. *
Potentilla monspeliensis L.
P. recta L. *
P. simplex Michx.
Prunus americana Marsh.
P. glandulosa Thunb. #*
P. hortulana Bailey
P. institia L. X
P. lanata (Sudw.) Mack. & Bush
P. persica (L.) Batsch. *
P. serotina Ehrh.
P. virginiana L.
Pyrus communis L. *
Rosa carolina L.
R. eglanteria L. *
R. multiflora Thunb. *
R. setigera Michx.
Rubus allegheniensis Porter
R. flagellaris Willd.
R. idaeus L.
R. occidentalis L.
R. pennsylvanicus Poir.
Spiraea vanhouttei Zabel #*

RUBIACEAE

Cephalanthus occidentalis L.
Galium aparine L.
G. circaezans Michx.
G. concinnum T. & G.
G. triflorum Michx.

RUTACEAE

Phellodendron amurense Rupr. #*
Zanthoxylum americanum L.

SALICACEAE

Populus deltoides Marsh.
Salix amygdaloides Anders.
S. interior Rowlee
S. nigra Marsh.

SANTALACEAE

Comandra umbellata (L.) Nutt.

SAXIFRAGACEAE

Heuchera hirsuticaulis (Wheelock) Rydb.
H. richardsonii R. Br.

SCROPHULARIACEAE

Aureolaria grandiflora (Benth.) Pennell
Chaenorrhinum minus (L.) Lange *
Dasistoma macrophylla (Nutt.) Raf.
Gerardia gattingeri Small
G. skinneriana Wood. X
G. tenuifolia Vahl.
Gratiola neglecta Torr.
Leucospora multifida (Michx.) Nutt.
Lindernia dubia (L.) Pennell
Mimulus alatus Ait.
M. ringens L.
Penstemon pallidus Small
Scrophularia marilandica L.
Verbascum blattaria L. *
V. thapsus L. *
Veronica arvensis L. *
V. peregrina L.
Veronicastrum virginicum (L.) Farw.

SIMARUBACEAE

Ailanthus altissima (Mill.) Swingle X*

SOLANACEAE

Datura stramonium L. *
Lycopersicon esculentum Mill. *
Petunia axillaris BSP *
Physalis heterophylla Nees
P. pubescens L.
P. subglabrata Mack. & Bush
Solanum nigrum L.
S. carolinense L.

STAPHYLEACEAE

Staphylea trifoliata L.

TILIACEAE

Tilia americana L.

ULMACEAE

Celtis occidentalis L.
Ulmus americana L.
U. rubra Muhl.

UMBELLIFERAE

Chaerophyllum procumbens (L.) Crantz.
Cicuta maculata L.
Conium maculatum L. *
Cryptotaenia canadensis (L.) DC.
Daucus carota L. *
Osmorhiza claytonii (Michx.) Clarke
O. longistylis (Torr.) DC.
Pastinaca sativa L. *
Sanicula canadensis L.
S. gregaria Bickn.
Taenida integerrima (L.) Drude
Thaspium barbinode (Michx.) Nutt.
Zizia aurea (L.) Koch

URTICACEAE

Boehmeria cylindrica (L.) Sw.
Laportea canadensis (L.) Gaud.
Parietaria pennsylvanica Muhl.
Pilea pumila (L.) Gray
Urtica gracilis Ait.

VERBENACEAE

Phyla lanceolata (Michx.) Greene
Verbena bracteata Lag. & Rodr.
V. hastata L.
V. stricta Vent.
V. urticifolia L.

VIOLACEAE

Viola eriocarpa Schw.
V. incognita Brainerd
V. missouriensis Greene
V. papilionacea Pursh
V. pedata L.
V. rafinesquii Greene
V. sororia Willd.

VITACEAE

Ampelopsis cordata Michx.
Parthenocissus quinquefolia (L.) Planch.
Vitis aestivalis Michx. X
V. cinerea Engelm.
V. riparia Michx.
V. vulpina L.

Class Monocotyledoneae

AMARYLLIDACEAE

Hypoxis hirsuta (L.) Coville
Narcissus jonquilla Jonquil #*
N. poeticus L. #*

ARACEAE

Arisaema dracontium (L.) Schott.
A. triphyllum (L.) Schott.

COMMELINACEAE

Commelina communis L.
Tradescantia ohiensis Raf.

CYPERACEAE

Carex albursina Sheldon
C. blanda Dewey
C. brevior (Dewey) Mack.
C. cephalophora Muhl.
C. conjuncta Boott
C. convoluta Mack.
C. davisii Schw. & Torr.
C. festucacea Schk.
C. gracilescens Steud.
C. granularis Muhl.
C. grayii Carey
C. grisea Wahl.
C. hirsutella Mack.
C. lupuliformis Sartw.
C. muhlenbergii Schk.
C. normalis Mack.
C. pensylvanica Lam.
C. shortiana Dewey
C. tribuloides Wahl.
C. vulpinoidea Michx.
Cyperus erythrorhizos Muhl.
C. ferruginescens Boeck.
C. filiculmis Vahl.
C. strigosus L.
Eleocharis calva Torr.
Scirpus atrovirens Willd.
S. lineatus Michx.

DIOSCOREACEAE

Dioscorea villosa L.

GRAMINEAE

Agropyron repens (L.) Beauv. *
Agrostis alba L. *
A. hyemalis (Walt.) BSP.
Andropogon furcatus Muhl.
A. scoparius Michx.
A. virginicus L.
Aristida oligantha Michx.
Avena sativa L. *
Brachyelytrum erectum (Schreb.) Beauv.
Bromus asper Murray
B. inermis Leyss. *
B. japonicus Thunb. *
B. purgans L.
B. tectorum L. *
Cenchrus pauciflorus Benth. *
Cinna arundinacea L.
Dactylis glomerata L. *

Danthonia spicata (L.) Beauv.
Diarrhena americana Beauv.
Digitaria ischaemum (Schreb.) * Schreb.
D. sanguinalis (L.) Scop. *
Echinochloa crusgalli (L.) Beauv. *
Eleusine indica (L.) Gaertn. *
Elymus canadensis L.
E. villosus Muhl.
E. virginicus L.
Eragrostis capillaris (L.) Nees
E. cilianensis (All.) Lut. *
E. hypnoides (Lam.) BSP.
E. pectinacea (Michx.) Nees
Festuca elatior L.
F. obtusa Bieler
F. octoflora Walt.
Glyceria septentrionalis Hitchc.
G. striata (Lam.) Hitchc.
Hordeum jabatum L.
H. pusillum Nutt.
Hystrix patula Moench
Leersia lenticularis Michx.
L. oryzoides (L.) Sw.
L. virginica Willd.
Lolium perenne L. *
Muhlenbergia frondosa (Poir.) Fern.
M. schreberi J. F. Gmel.
M. sobolifera (Muhl.) Trin.
M. sylvatica Torr.
Panicum capillare L.
P. clandestinum L.
P. depauperatum Muhl.
P. dichotomiflorum Michx.
P. huachucae Ashe
P. latifolium L.
P. lindheimeri Nash
P. linearifolium Scribn.
P. scribnerianum Nash
P. virgatum L.
Paspalum pubescens Muhl.
Phleum pratense L. *
Poa annua L. *
P. compressa L. *
P. pratensis L. *
P. sylvestris Gray
Setaria faberii Herm. *
S. lutescens (Wiegel.) F. T. Hubb. *
S. verticillata (L.) Beauv. *
S. viridis (L.) Beauv. *
Sorghastrum nutans (L.) Nash
Sporobolus asper (Michx.) Kunth
Tridens flavus (L.) Hitchc.
Triticum aestivum L. *
Zea mays L. *

IRIDACEAE

Belamcanda chinensis (L.) DC. #*
Iris germanica L. #*
Sisyrinchium albidum Raf.
S. bermudiana L.
S. campestre Bickn.

JUNCACEAE

Juncus dudleyi Wieg.
J. interior Wieg.
J. secundus Beauv.
J. tenuis Willd.

LEMNACEAE

Lemna minor L.

LILIACEAE

Allium canadense L.
A. sativum L. *
A. vineale L. *
Asparagus officinalis L. *
Erythronium albidum Nutt.
Hemerocallis fulva L. *
Lilium michiganense Farw.
L. tigrinum Ker *
Ornithogalum umbellatum L. #*
Polygonatum commutatum (Schultes) Dietr.
Smilicina racemosa (L.) Desf.
Smilax ecirrhata (Engelm.) Wats.
S. hispida Muhl.
S. lasioneura Hook.
Trillium grandiflorum (Michx.) Salisb.
T. recurvatum Beck.
Uvularia grandiflora Sm.
Yucca filamentosa L. *

ORCHIDACEAE

Liparis lilifolia (L.) Rich.
Spiranthes cernua (L.) Rich.

POTAMOGETONACEAE

Potamogeton foliosus Raf.

TYPHACEAE

Typha angustifolia L.
T. latifolia L.

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VASCULAR PLANTS IN WALNUT POINT STATE PARK, DOUGLAS COUNTY, ILLINOIS

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ABSTRACT - A total of 503 taxa of vascular plants, representing 301 genera in 93 families, have been collected in Walnut Point State Park, Douglas County, Illinois. The checklist has been annotated to indicate the habitats in which each taxon was collected and observed.

Walnut Point State Park is a relatively new park with most of its area previously being a part of the Douglas County Conservation Area. It is located in the Embarras River valley about three miles north of Oakland, Illinois (Sect. 35 & 36, T15N, R10E: Sect. 1, T14N, R10E), and is at the southern edge of the Grand Prairie Section of the Grand Prairie Division (Schwegman, 1973). Though a part of the Grand Prairie Division, much of the area in and around the park was originally in forest. This forest was typically present in the much dissected and well drained areas near the major streams and rivers in central Illinois (Ebinger, 1973). Presently much of this forest has been cleared for agriculture while the small amount remaining has usually been heavily logged and grazed.

The forested areas within the park represent the best remaining examples of stream-side forests in the upper part of the Embarras River watershed. Though some cutting and grazing has occurred, the forest has a good composition and the trees average better than 12 inches d.b.h. The remainder of the park was cultivated and now harbors succession-type vegetation. Parts of this area are now in pine plantations of various ages.

A total of 503 taxa of vascular plants in 93 families were found growing in the park. Of the taxa collected, 14 are ferns, fern-allies, or gymnosperms, 122 are monocots, and 367 are dicots. Of this latter group, 80 are trees, shrubs or woody vines, while 287 are herbaceous. The largest family represented is the Gramineae with 60 taxa followed by the Compositae with 56.

In the following list the nomenclature follows that of Mohlenbrock (1975). The families are listed in alphabetic order within the major groups to facilitate the finding of names, while the species are arranged in alpabetic order under the families. The numbers following the binomials indicate the habitat types where the species was collected and observed (1= upland woods; 2= wooded hillside; 3= lowland woods; 4= disturbed, open woods; 5= open area and waste ground; 6= aquatic and shoreline; 7= hillside marsh). An asterisk (*) indicates that the taxon has not been previously recorded for Douglas County by Jones and Fuller (1955), Winterringer and Evers (1960), Mohlenbrock (1967, 1970a, 1970b, 1972, 1973), Dolbeare and Ebinger (1974), or Sheviak (1974). All specimens are deposited in the Stover Herbarium of Eastern Illinois University, Charleston, Illinois (EIU).

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FERNS AND FERN ALLIES

Ophioglossaceae

Botrychium dissectum Spreng. var. obliquum (Muhl.) Clute. 1,2
Botrychium virginianum (L.) Sw. 1

Equisetaceae

Equisetum arvense L. 6
Equisetum hyemale L. 2

Polypodiaceae

Adiantum pedatum L. 1,2
Asplenium platyneuron (L.) Oakes.* 2,5
Athyrium filix-femina (L.) Roth. var. rubellum Gilb.* 1,2
Athyrium thelypterioides (Michx.) Desv.* 2
Cystopteris fragilis (L.) Bernh. 2,4
Onoclea sensibilis L.* 1
Thelypteris hexagonoptera (Michx.) Weatherby.* 1

Selaginellaceae

Selaginella apoda (L.) Fern.* 6

GYMNOSPERMAE

Cupressaceae

Juniperus virginiana L.* 5

Pinaceae

Pinus strobus L. intro.

MONOCOTYLEDONEAE

Alismaceae

Alisma subcordatum Raf. 6

Araceae

Acorus calamus L.* 6
Arisaema dracontium (L.) Schott. 2,3
Arisaema triphyllum (L.) Schott. 1,2

Commelinaceae

Commelina communis L. 3,6
Tradescantia subaspera Ker.* 2,3
Tradescantia virginiana L. 1,2,4

Cyperaceae

Carex blanda Dewey. 1,4
Carex conjuncta Boott. 4
Carex convoluta Mack.* 1,2,4
Carex cristatella Britt. 1,4,5
Carex davisii Schwein & Torr. 4
Carex frankii Kunth. 6
Carex granularis Muhl.* 4
Carex gravida Bailey.* 5
Carex grayi Carey. 2,3
Carex grisea Wahlenb. 1,4
Carex hirsutella Mack.* 4,5
Carex hirtifolia Mack.* 1,2
Carex jamesii Schwein.* 4
Carex lurida Wahlenb.* 6
Carex pensylvanica Lam.* 1,2
Carex shortiana Dewey. 4,6
Carex sparganioides Muhl.* 4,5
Carex stipata Muhl.* 6
Carex vulpinoides Michx. 5,6
Cyperus ferruginescens Boeckl.* 6
Cyperus strigosus L. 5,6
Scirpus atrovirens Willd. 5,6
Scirpus pendulus Muhl. 5,6
Scirpus validus Vahl.* 5,6

Dioscoreaceae

Dioscorea villosa L.* 1

Iridaceae

Iris shrevei Small.* 6
Sisyrinchium albidum Raf.* 5
Sisyrinchium angustifolium Mill.* 5

Juncaceae

Juncus interior Wieg. 4,5
Juncus tenuis Willd. 5
Juncus torreyi Coville. 5

Lemnaceae

Lemna minor L. 6
Wolffia columbiana Karst. 6

Liliaceae

Allium canadense L. 4,5
Allium tricoccum Ait.* 2,3
Allium vineale L. 5
Camassia scilloides (Raf.) Cory. 1
Erythronium albidum Nutt. 2
Hemerocallis fulva L. 5
Hypoxis hirsuta (L.) Coville.* 1
Ornithogalum umbellatum L.* 5
Polygonatum commutatum (Schult.) A. Dietr. 1,2
Smilacina racemosa (L.) Desf. 1,2
Trillium recurvatum Beck. 1,2
Uvularia grandiflora Sm. 1,2

Orchidaceae

Aplectrum hyemale (Muhl.) Torr.* 2
Corallorhiza odontorhiza (Willd.) Nutt.* 1
Cypripedium calceolus L. var. pubescens (Willd.) Correll.* 1
Liparis liliifolia (L.) Rich.* 4
Spiranthes ovalis Lindl. 4

Poaceae

Agropyron repens (L.) Beauv. 5
Agrostis alba L. 4,5,6
Agrostis perennans (Walt.) Tuckerman.* 4
Alopecurus pratensis L.* 5
Andropogon virginicus L.* 5
Arrhenatherum elatius (L.) Presl.* 5
Avena sativa L. intro.
Brachyelytrum erectum (Schreb.)Beauv.* 1
Bromus commutatus Schrad.* 5
Bromus inermis Leyss. 5
Bromus pubescens Muhl.* 1,2,5
Bromus purgans L.* 1
Bromus tectorum L. 5
Chasmanthium latifolium (Michx.) Yates.* 2,3
Cinna arundinacea L. 2,3
Dactylis glomerata L. 5
Danthonia spicata (L.) Beauv.* 4
Diarrhena americana Beauv.* 1,2
Digitaria ischaemum (Schreb.) Muhl.* 5
Digitaria sanguinalis (L.) Scop. 5
Echinochloa crusgalli (L.) Beauv.* 5,6
Eleusine indica (L.) Gaertn. 5
Elymus canadensis L. 5
Elymus hystrix L.* 4,5
Elymus villosus Muhl. 4
Elymus virginicus L. 4,5
Eragrostis cilianensis (All.) Mosher. 5
Eragrostis hypnoides (Lam.) BSP.* 6
Eragrostis pectinacea (Michx.) Nees. 5
Festuca obtusa Bieler. 1,2
Festuca pratensis Huds. 5
Glyceria striata (Lam.) Hitchc.* 5,6
Hordeum pusillum Nutt. 5
Leersia oryzoides (L.) Swartz. 6
Leersia virginica Willd.* 4,6
Lolium perenne L.* 5
Muhlenbergia frondosa (Poir.) Fern.* 4
Muhlenbergia schreberi J.F.Gmel.* 4,5
Muhlenbergia sobolifera (Muhl.) Trin.* 1,2,4
Muhlenbergia tenuiflora (Willd.) BSP.* 4,5
Panicum capillare L. 5
Panicum dichotomiflorum Michx. 5
Panicum lanuginosum Ell. 4,5
Panicum latifolium L.* 4,5
Paspalum ciliatifolium Michx.* 5
Phalaris arundinacea L.* 5
Phleum pratense L. 5
Poa chapmaniana Scribn.* 5
Poa compressa L. 4,5
Poa pratensis L. 4,5
Poa sylvestris Gray. 1,2
Setaria faberi Herrm. 5
Setaria lutescens (Weigel) Hubb. 5
Setaria viridis (L.) Beauv. 5
Sphenopholis obtusata (Michx.) Scribn. var. major (Torr.) Erdman. 4
Sporobolus aspera (Michx.) Kunth. 5
Sporobolus neglectus Nash.* 5
Sporobolus vaginiflorus (Torr.) Wood.* 5
Tridens flavus (L.) Hitchc. 5
Triticum aestivum L. intro.

Potamogetonaceae

Potamogeton foliosus Raf. 6

Smilacaceae

Smilax ecirrata (Engelm.) S. Wats. 1,2
Smilax hispida Muhl. 4,5
Smilax lasioneuron Hook. 5

Typhaceae

Typha latifolia L. 6

DICOTYLEDONEAE

Acanthaceae

Ruellia strepens L. 5

Aceraceae

Acer negundo L. 3,5
Acer saccharinum L. 3
Acer saccharum Marsh. 1,2

Aizoaceae

Mollugo verticillata L. 5

Amaranthaceae

Amaranthus hybridus L. 5
Amaranthus spinosus L.* 5
Amaranthus tamariscinus Nutt. 6

Anacardiaceae
Rhus glabra L. 5
Toxicodendron radicans (L.) Kuntze. 1,2,3,4,5

Apocynaceae
Apocynum cannabinum L. 5

Araliaceae
Panax quinquefolius L.* 1,2

Aristolochiaceae
Aristolochia serpentaria L.* 1
Asarum canadense L. var. reflexum (Bickn.) Robins.* 2

Asclepiadaceae
Asclepias exaltata L.* 1
Asclepias incarnata L. 6
Asclepias purpurascens L.* 4,5
Asclepias syriaca L. 5
Asclepias verticillata L. 5
Cynanchum laeve (Michx.) Pers. 5

Balsaminaceae
Impatiens biflora Walt.* 3,4,5,6,7
Impatiens pallida Nutt.* 3,7

Berberidaceae
Caulophyllum thalictroides (L.) Michx.* 2
Podophyllum peltatum L. 1,2,4

Betulaceae
Betula nigra L. intro.
Carpinus caroliniana Walt.* 1,2
Corylus americana Walt.* 1,2
Ostrya virginiana (Mill.) K. Koch.* 1,2

Bignoniaceae
Campsis radicans (L.) Seem. 5

Boraginaceae
Hackelia virginiana (L.) I.M.Johnston.* 1,2,5
Mertensia virginica (L.) Pers. 1
Myosotis virginica (L.) BSP. 5

Campanulaceae
Campanula americana L. 1,2
Lobelia inflata L. 4,5
Lobelia spicata Lam. 4
Lobelia siphilitica L.* 5,6
Specularia perfoliata (L.) A. DC.* 4,5

Caprifoliaceae
Lonicera japonica Thunb.* 4,5
Lonicera prolifera (Kirchn.) Rehd.* 2,4
Sambucus canadensis L. 4,5
Symphoricarpos orbiculatus Moench. 4,5
Triosteum aurantiacum Bickn. 5
Triosteum perfoliatum L. 1,4
Viburnum prunifolium L.* 1,4
Viburnum recognitum Fern.* 1,4

Caryophyllaceae
Cerastium nutans Raf. 5
Cerastium vulgatum L.* 5
Dianthus armeria L.* 5
Lychnis alba Mill.* 5
Paronychia canadensis (L.) Wood. 5
Saponaria officinalis L. 5
Silene antirrhina L. 5
Silene stellata (L.) Ait. f. 1,4,5
Stellaria longifolia Muhl.* 5
Stellaria media (L.) Cyrill. 5

Celastraceae
Celastrus scandens L. 1,4,5
Euonymus atropurpureus Jacq. 2
Euonymus obovatus Nutt.* 2

Chenopodiaceae
Atriplex patula L.* 5
Chenopodium album L. 5
Chenopodium ambrosioides L. 5,6

Compositae
Achillea millefolium L. 4,5
Ambrosia artemisiifolia L. 4,5
Ambrosia trifida L. 5
Antennaria neglecta Greene.* 5
Antennaria plantaginifolia (L.) Richards.* 1,2,4
Anthemis cotula L. 5
Arctium minus (Hill) Bernh.* 5
Aster lateriflorus (L.) Britt.* 1,2
Aster pilosus Willd. 5
Aster sagittifolius Wedem. ex Willd.* 1
Aster shortii Lindl.* 1,2
Aster simplex Willd.* 3
Aster turbinellus Lindl.* 1,2
Bidens bipinnata L.* 3,6
Bidens cernua L.* 6
Bidens frondosa L. 3
Chrysanthemum leucanthemum L.* 4,5

Cirsium altissimum (L.) Spreng.* 4
Cirsium discolor (Muhl.) Spreng. 5
Cirsium vuglare (Savi) Tenore. 5
Eclipta alba (L.) Hassk.* 6
Erigeron annuus (L.) Pers. 4,5
Erigeron canadensis L. 5
Erigeron philadelphicus L. 4,5
Eupatorium coelestinum L. 6
Eupatorium perfoliatum L.* 6,7
Eupatorium purpureum L. 4,5
Eupatorium rugosum Houtt.* 1,2,4,5
Eupatorium serotinum Michx. 4,5
Eupatorium sessilifolium L. 2
Galinsoga ciliata (Raf.) Blake.* 6
Gnaphalium obtusifolium L.* 5
Helianthus divaricatus L. 4,5
Helianthus tuberosus L. 5
Heliopsis helianthoides (L.) Sweet. 4,5
Krigia biflora (Walt.) Blake.* 1
Lactuca canadensis L. 4,5
Lactuca floridana (L.) Gaertn.* 5
Lactuca serriola L. 5
Prenanthes altissima L.* 1,2
Rudbeckia hirta L. 5
Rudbeckia laciniata L. 3
Rudbeckia triloba L. 5
Senecio obovatus Muhl.* 2
Silphium perfoliatum L.* 6
Solidago canadensis L. 5
Solidago flexicaulis L.* 2
Solidago nemoralis Ait.* 4,5
Solidago patula Muhl.* 7
Solidago ulmifolia Muhl. 1,2
Taraxacum officinale Weber. 5
Tragopogon dubius Scop.* 5
Verbesina alternifolius (L.) Britt.* 3,4,5
Vernonia gigantea (Walt.) Trel. 5
Vernonia missurica Raf. 5
Xanthium strumarium L. var. canadensis (Mill.) Torr. & Gray. 3

Convolvulaceae

Calystegia sepium (L.) R. Br. 5
Cuscuta gronovii Willd.* 3
Ipomoea hederacea (L.) Jacq. 5
Ipomoea pandurata (L.) G.F.W. Mey.* 5

Cornaceae

Cornus drummondii C.A. Mey. 4,5
Cornus florida L.* 1,2
Cornus obliqua Raf.* 4,5
Cornus racemosa Lam. 1,2

Cruciferae

Arabis laevigata (Muhl.) Poir.* 2,4
Arabis hirsuta (L.) Scop. var. pycnocarpa (M. Hopkins) Rollins.* 4
Capsella bursa-pastoris (L.) Medic. 5
Cardamine bulbosa (Schreb.) BSP.* 2,7
Cardamine pensylvanica Muhl.* 6
Dentaria laciniata Muhl. 1,2
Draba verna L.* 5
Iodanthus pinnatifidus (Michx.) Steud.* 3
Lepidium campestre (L.) R. Br. 5
Lepidium virginicum L. 5
Sisymbrium officinale (L.) Scop. 5

Ebenaceae

Diospyros virginiana L.* 4,5

Ericaceae

Monotropa hypopithys L.* 2

Euphorbiaceae

Acalypha gracilens Gray.* 5
Acalypha rhomboidea Raf. 5
Acalypha virginica L. 5,6
Chamaesyce maculata (L.) Small. 5
Chamaesyce supina (Raf.) Moldenke. 5
Croton capitatus Michx.* 5
Euphorbia corollata L. 4,5

Fagaceae

Quercus alba L. 1,2,4
Quercus imbricaria Michx. 4,5
Quercus macrocarpa Michx. 2,3
Quercus muhlenbergii Engelm.* 2
Quercus rubra L. 1,2,4
Quercus velutina Lam. 1,2,4

Gentianaceae

Sabatia angularis (L.) Pursh.* 5
Swertia caroliniensis (Walt.) Kuntze.* 1.2

Geraniaceae

Geranium carolinianum L.* 5
Geranium maculatum L. 2

Hydrophyllaceae

Ellisia nyctelea L. 5
Hydrophyllum canadense L.* 2
Hydrophyllum virginianum L. 2
Phacelia purshii Buckley.* 2

Hypericaceae

Hypericum punctatum Lam. 6

Juglandaceae

Carya cordiformis (Wang.) K. Koch. 1,2
Carya glabra (Mill.) Sweet. 1,2
Carya ovalis (Wang.) Sarg. 4
Carya ovata (Mill.) K. Koch. 1,2
Carya tomentosa (Poir.) Nutt. 1,2
Juglans nigra L. 1,2

Labiatae

Agastache nepetoides (L.) Ktze.* 4,5
Blephilia hirsuta (Pursh) Benth.* 5
Glechoma hederacea L.* 5
Isanthus brachiatus (L.) BSP.* 5
Lamium amplexicaule L. 5
Leonurus cardiaca L.* 5
Lycopus americanus Muhl. 6
Lycopus virginicus L.* 6
Mentha arvensis L. var. villosa (Benth.) S.R. Stewart.* 6
Monarda bradburiana Beck.* 4
Nepeta cataria L. 4,5
Prunella vulgaris L. var. lanceolata (Bart.) Fern. 6
Pycnanthemum tenuifolium Schrad. 4,5
Pycnanthemum pilosum Nutt. 5
Pycnanthemum virginianum (L.) Dur. & Jacks. 5
Scutellaria incana Biehler.* 1
Scutellaria lateriflora L.* 6
Scutellaria parvula Michx. var. leonardii (Epling) Fern. 4
Scutellaria ovata Hill. var. versicolor (Nutt.) Fern.* 1
Stachys tenuifolia Willd. 4,5
Teucrium canadense L. var. virginicum (L.) Eat. 5

Lauraceae

Lindera benzoin (L.) Blume.* 3
Sassafras albidum (Nutt.) Nees.* 4,5

Leguminosae

Amphicarpa bracteata (L.) Fern.* 4
Baptisia leucantha Torr. & Gray. 5
Cassia fasciculata Michx. 5
Cassia marilandica L.* 5
Cercis canadensis L. 1,2
Desmodium glutinosum (Muhl.) Wood.* 1
Desmodium nudiflorum (L.) DC.* 1,4
Desmodium paniculatum (L.) DC.* 1,4
Desmodium sessilifolium (Torr.) Torr. & Gray.* 5
Gleditsia triacanthos L. 4,5
Gymnocladus dioica (L.) K. Koch.* 2,3
Lespedeza cuneata (Dum.-Cours.) G. Don.* 5
Lespedeza stipulacea Maxim.* 5
Lespedeza violacea (L.) Pers.* 5
Medicago lupulina L. 5
Medicago sativa L. 5
Melilotus alba Desr. 5
Melilotus officinalis (L.) Lam. 5
Psoralea onobrychis Nutt. 5
Trifolium campestre Schreb. 5
Trifolium hybridum L. 5
Trifolium pratense L. 5
Trifolium repens L. 5

Malvaceae

Abutilon theophrastii Medic. 5
Hibiscus militaris Cav. 3,6
Hibiscus trionum L. 5
Malva rotundifolia L.* 5
Sida spinosa L. 5

Menispermaceae

Menispermum canadense L. 1,4

Moraceae

Humulus lupulus L. 4,5
Maclura pomifera (Raf.) Schneider. 5
Morus rubra L. 4,5

Nyctaginaceae

Mirabilis nyctaginea (Michx.) MacM. 5

Oleaceae

Fraxinus americana L. 1,2
Fraxinus pennsylvanica Marsh. var. subintegerrima (Vahl.) Fern. 3

Onagraceae

Circaea quadrisulcata (Maxim.) Franch. & Sav. var. canadensis (L.) Hara.* 1
Epilobium coloratum Muhl. 6
Oenothera biennis L. 5,6

Orobanchaceae

Orobanche uniflora L.* 1

Oxalidaceae
Oxalis dillenii Jacq. 1,4,5
Oxalis violacea L. 1,4

Papaveraceae
Dicentra cucullaria (L.) Bernh. 2
Sanguinaria canadensis L. 2

Passifloraceae
Passiflora lutea L. var. glabriflora Fern.* 1

Phrymaceae
Phryma leptostachya L.* 1,2

Phytolaccaceae
Phytolacca americana L. 5

Plantaginaceae
Plantago aristata Michx. 5
Plantago lanceolata L. 5
Plantago rugelii Dcne. 5
Plantago virginica L.* 5

Platanaceae
Platanus occidentalis L. 5

Polemoniaceae
Phlox divaricata L. 1,2,4
Phlox paniculata L.* 3,5
Polemonium reptans L. 1,2

Polygalaceae
Polygala verticillata L.* 5

Polygonaceae
Polygonum aviculare L.* 5,6
Polygonum convolvulus L. 5
Polygonum hydropiper L.* 5
Polygonum pensylvanicum L. var. laevigatum Fern. 5
Polygonum persicaria L. 5
Polygonum punctatum Ell. 5
Polygonum scandens L.* 5
Polygonum virginianum L.* 1,2
Rumex acetosella L. 5
Rumex altissimus Wood.* 5
Rumex crispus L.* 5
Rumex obtusifolius L.* 1,6

Portulacaceae
Claytonia virginica L. 1,2,4

Primulaceae
Lysimachia ciliata L. 5
Lysimachia lanceolata Walt. 5
Lysimachia nummularia L.* 3
Samolus parviflorus Raf. 6

Ranunculaceae
Actaea pachypoda Ell.* 1,2
Anemone virginiana L.* 4
Caltha palustris L.* 7
Clematis pitcheri Torr. & Gray. 3
Hepatica nobilis Schreb. var. acuta (Pursh) Steyerm.* 2
Isopyrum biternatum (Raf.) Torr. & Gray* 1,2
Myosurus minimus L. 5
Ranunculus abortivus L. 3,4,5,7
Ranunculus micranthus Nutt.* 5
Ranunculus recurvatus Poir.* 1,2
Ranunculus septentrionalis Poir. 3.7
Thalictrum dasycarpum Fisch. & Lall.* 2
Thalictrum dioicum L.* 1,2

Rhamnaceae
Ceanothus americanus L. 4

Rosaceae
Agrimonia parviflora Ait.* 5
Agrimonia pubescens Wallr.* 1,2
Agrimonia rostellata Wallr. 4
Crataegus crus-galli L. 5
Crataegus mollis (Torr. & Gray) Scheele. 5
Fragaria virginiana Duchesne. 4,5
Geum canadense Jacq. 4,5
Geum vernum (Raf.) Torr. & Gray. 4,5
Gillenia stipulata (Muhl.) Baill.* 4
Malus ioensis (Wood) Britt. 4,5
Malus pumila Mill.* 5
Potentilla norvegica L. 5
Potentilla recta L.* 5
Potentilla simplex Michx. 4,5
Prunus persica (L.) Batsch.* 5
Prunus serotina Ehrh. 2,4,5
Pyrus communis L.* 5
Rosa carolina L. 4
Rosa multiflora Thunb.* 5
Rosa setigera Michx. 6
Rubus allegheniensis Porter. 5
Rubus argutus Link.* 4,5
Rubus flagellaris Willd.* 5
Rubus occidentalis L.* 4,5

Rubiaceae
Cephalanthus occidentalis L. 3,6
Galium aparine L. 1,2,4
Galium circaezans Michx.* 1,4
Galium concinnum Torr. & Gray. 1,2
Galium triflorum Michx.* 1
Houstonia purpurea L. 4,5

Rutaceae
Xanthoxylum americanum Mill.* 2

Salicaceae
Populus deltoides Marsh. 3,5
Populus grandidentata Michx.* 5
Salix discolor Muhl.* 5,7
Salix interior Rowlee. 6
Salix nigra Marsh. 6

Saururaceae
Saururus cernuus L. 3

Saxifragaceae
Heuchera hirsuticaulis (Wheelock) Rydb.* 4,5
Hydrangea arborescens L.* 2
Penthorum sedoides L. 6
Ribes missouriense Nutt. 1,4

Scrophulariaceae
Conobea multifida (Michx.) Benth. 6
Gerardia tenuifolia Vahl.* 4
Lindernia dubia (L.) Pennell. 6
Mimulus alatus Ait. 4,5
Mimulus ringens L. 6
Penstemon digitalis Nutt. 5
Scrophularia marilandica L. 4,5
Seymeria macrophylla Nutt.* 4
Verbascum blattaria L. 5
Verbascum thapsus L. 5
Veronica arvensis L. 5
Veronica peregrina L. 5
Veronicastrum virginicum (L.) Farw. 1

Simarubaceae
Ailanthus altissima (Mill.) Swingle.* 5

Solanaceae
Datura stramonium L. 5
Physalis heterophylla Nees. 6
Physalis subglabrata Mack. & Bush. 5
Solanum carolinense L. 5
Solanum americanum Mill.* 5,6

Staphyleaceae
Staphylea trifolia L. 2,3

Tiliaceae
Tilia americana L.* 2

Ulmaceae
Celtis occidentalis L. 3,4
Ulmus americana L. 2,3,5
Ulmus rubra Muhl. 1,2,3,5

Umbelliferae
Chaerophyllum procumbens (L.) Crantz. 1,2
Conium maculatum L. 5
Cryptotaenia canadensis (L.) DC.* 1,2
Daucus carota L. 5
Osmorhiza claytonii (Michx.) Clarke.* 2,3
Osmorhiza longistylis (Torr.) DC. 1,2
Pastinaca sativa L. 5
Sanicula canadensis L.* 1,2
Sanicula gregaria Bickn. 1,2
Torilis japonica (Houtt.) DC.* 5

Urticaceae
Boehmeria cylindrica (L.) Sw.* 3,6
Laportea canadensis (L.) Webb.* 3,7
Parietaria pensylvanica Muhl.* 1,2
Pilea pumila (L.) Gray. 3,7

Verbenaceae
Lippia lanceolata Michx. 6
Verbena hastata L. 5,6
Verbena stricta Vent. 5
Verbena urticifolia L. 4,5

Violaceae
Viola pratincola Greene. 3,4
Viola pratincola Greene. f. albiflora (Glover) Mohl.* 5
Viola pubescens Ait. var. eriocarpa (Schwein.) Russell. 2,3
Viola rafinesquii Greene.* 5
Viola sororia Willd. 4

Vitaceae
Parthenocissus quinquefolia (L.) Planch. 5
Vitis aestivalis Michx. 1,4,5
Vitis riparia Michx. 5
Vitis vulpina L. 5

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STAND STRUCTURE AND COMPOSITION OF A NATURAL MIXED HARDWOOD FOREST

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Abstract

A complete inventory of a 60-acre natural mixed hardwood forest was conducted to study its stand structure and composition. The current status of the woodland was compared with data from the 1963 inventory. In the present stand the leading dominant is sugar maple. Hackberry, slippery elm, white ash and basswood follow in order of Importance Value Index. The relative species composition did not change significantly after the impact of the Dutch elm disease, but most species showed an increase in number of trees and basal area. The total stand had a basal area of 120.8 square feet (trees 2.6 inch diameter and larger), with 231.6 trees per acre. Sugar Maple can be expected to maintain its dominance in the future as it represents approximately one third of all individuals in the seedling and sapling stage.

Forests in central Illinois once were found mainly along watercourses and in isolated patches known as "Prairie Groves" that were separated from the main bodies of timber (Boggess 1964). With settlement many of these forest lands were converted to agricutlrual use, with only a few remnants remaining. The University of Illinois acquired several of these woodlands maintaining them as natural areas for research and educational purposes. The two major remnants of the "Big Grove" near Urbana, Illinois are Brownfield Woods and Trelease Woods. Brownfield Woods has been owned by the University of Illinois since 1939 and Trelease Woods since 1917. Results of an analysis of the stand composition of Brownfield Woods was reported previously (Miceli et. al. 1977). This paper summarizes the results of a 100% inventory of Trelease Woods conducted in 1976. Both of the woodlands are classified as mesophytic upland forests.

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Trelease Woods is a 60-acre woodland located northeast of Urbana, Illinois in the SW¼ of Section 1, Range 9E, Township 19N, Champaign County Illinois. Topography is flat with elevation differences of less than 5 m. The major soil orders are Mollisols and Alfisols which are developed in shallow loess (3 feet or less) over glacial till (Bailey et. al., 1964). The Mollisols predominate with the weakly developed transition Alfisols occurring in only a few areas of the woodland.

PAST WORK

The first inventory of Trelease Woods was completed in 1922 as a tree count by species (McDougall, 1922). In 1935 a study on plot size requirements was conducted giving results on stand composition (Marberry 1936) and in 1940 this study was continued including additional plots (Vestal and Heermans 1945). Boggess conducted the first 100% inventory in 1963 examining the effect of Dutch elm disease occurring in the early 1950's on the forest. All references to past results are based on Boggess (1964).

METHODS

In designing the inventory the measurement system of Boggess (1964) was followed since a comparison with the 1963 inventory was desired. The area is subdivided in 96, 50-meter square blocks. For measurement purposes each block was subdivided into quarters (quadrats) by running a line diagonally from each corner post. All woody vegetation 2.6 inches dbh and above was measured to the nearest 0.1 inch by species. The saplings (0.6 to 2.5 diameter class) were measured in two 5 x 5 meter subplots in each block distributed systematically over the area. Tree seedlings were sampled in 2 x 2 meter plots located randomly in one corner of the 25 m^2 plot. Seedlings of woody species less than 0.6 inch in diameter were tallied by height in two classes (1) less than 1 foot and (2) greater than 1 foot.

In sampling reproduction and shrub species a total of 192 plots of 5 x 5 m and the same number of 2 x 2 m plots were measured, doubling the number used in 1963. This corresponds to a sampling intensity of 2% and 0.3% respectively, only a small sample of the entire area, which should be considered in evaluating results.

Tree data reported by diameter class, basal area, frequency and density in Table 1 and a comparison of earlier inventories in terms of basal area is shown in Table 2. Table 3 shows the density and frequency of seedlings and saplings by height or diameter class. The Importance Value Index is also shown in Table 1 and is calcualted as the sum of the relative density and the relative dominance for each species as in Boggess (1964).

RESULTS AND DISCUSSION

A total of 13,733 trees of 2.6 inch diameter or larger were measured resulting in an average number of 231.6 trees/acre. This compares to a total of 148.9 trees/acre in the 1963 inventory. The

Table 1. Number of Trees, Basal Area Per Acre, Importance Value Index, and Average Diameter for Leading Dominants.

	Diameter Class																	
	3-6		7-12		13-24		25-36		37+		Total		Percent		Average	Importance value	Frequency %	%
Species	BA	No.	BA	No.	BA	No.	BA	No.	BA	No.	BA	No.	BA	No.	diameter	index	quadrats	blocks
Sugar Maple	3.4	36.5	5.5	11.8	20.9	12.1	5.0	1.2	0.3	.	35.1	61.6	29.0	26.6	10.2	55.7	90.9	99.0
White Ash	0.6	5.3	1.4	3.1	8.2	4.1	4.4	1.1	0.4	0.1	15.0	13.6	12.4	5.9	14.2	18.3	61.8	95.8
Hackberry	1.4	12.2	4.9	10.7	3.1	2.3	2.8	0.6	1.1	0.1	13.4	26.0	11.1	11.2	9.7	22.3	80.7	96.9
Red Oak	.	0.1	.	0.1	1.2	0.5	7.1	1.4	2.9	0.4	11.2	2.4	9.3	1.0	29.5	10.3	27.3	64.6
Basswood	1.2	11.9	1.9	4.4	3.2	1.8	1.1	0.3	.	.	7.4	18.4	6.2	7.9	8.6	14.1	58.3	90.6
Slippery Elm	2.3	22.3	3.5	8.5	0.7	0.5	0.5	0.1	.	.	6.9	31.4	5.7	13.6	6.3	19.3	85.9	100.0
Black Walnut	0.4	3.9	0.8	1.8	2.4	1.2	3.0	0.7	.	.	6.6	7.6	5.5	3.3	12.6	8.7	44.3	78.1
Bur Oak	0.2	1.9	0.1	0.3	1.2	0.6	3.4	0.7	1.3	0.2	6.2	3.5	5.1	1.5	18.0	6.7	28.6	56.3
Buckeye	0.8	9.2	0.5	1.3	3.9	2.2	0.6	0.2	.	.	5.8	12.8	4.8	5.5	9.1	10.3	69.3	97.9
Blue Ash	0.2	2.6	0.5	1.2	0.9	0.5	0.7	0.2	.	.	2.4	4.4	2.0	1.9	9.9	3.9	40.6	72.9
American Elm	0.4	4.0	1.1	2.5	0.4	0.3	.	.	.	.	1.9	6.8	1.6	2.9	7.2	2.9	40.4	79.2
Hawthorn	0.6	5.8	0.6	1.7	0.2	0.1	.	.	.	.	1.4	7.7	1.1	3.3	5.8	4.5	31.0	59.4
Pawpaw	1.1	20.8	.	.	.	.	.	.	.	.	1.1	20.8	0.9	9.0	3.2	9.9	46.1	69.8
Chinquapin Oak	.	.	.	.	0.2	0.1	0.5	0.1	0.3	.	1.1	0.2	0.9	0.1	29.1	1.0	3.1	11.5
Kentucky Coffee Tree	0.1	1.3	0.2	0.5	0.5	0.3	0.2	0.1	.	.	1.0	2.1	0.9	0.9	9.4	1.8	17.2	42.7
Shagbark Hickory	0.2	1.4	0.2	0.7	0.5	0.3	0.1	.	.	.	1.0	2.4	0.8	1.0	8.8	1.8	18.2	41.7
Blue Beech	0.7	7.2	0.1	0.2	.	.	.	.	.	.	0.7	7.4	0.6	3.2	4.2	3.8	37.8	65.6
Sycamore	.	.	.	.	.	.	0.3	0.1	0.4	.	0.7	0.1	0.6	0.1	33.0	0.6	1.6	6.3
Green Ash	.	0.3	0.1	0.2	0.4	0.2	0.1	.	.	.	0.7	0.7	0.6	0.3	13.4	0.8	7.8	25.0
Silver Maple	.	.	.	.	.	.	0.3	0.1	.	.	0.4	0.1	0.3	0.1	23.2	0.3	0.5	2.1
Bitternut Hickory	.	0.2	.	.	0.2	0.1	.	.	.	.	0.2	0.3	0.2	0.1	11.7	0.3	4.4	15.6
Honey Locust	.	0.2	.	.	.	.	0.1	.	.	.	0.2	0.3	0.1	0.1	11.6	0.3	3.4	10.4
Others	0.1	0.6	0.1	0.1	0.1	0.1	0.1	.	0.2	.	0.4	1.0	0.3	0.5				
Total	13.7	147.7	21.5	49.1	48.2	27.3	30.3	6.9	6.9	0.8	120.8	231.6	100.0	100.0				

Table 2. Number of Trees and Basal Area Per Acre (sq. ft.) in 1940, 1963 and 1976 for 12 Species.

Species	1940		1963		1976	
	Number trees	Basal area (sq. ft.)	Number trees	Basal area (sq. ft.)	Number trees	Basal area (sq. ft.)
Sugar Maple	39.2	34.6	37.8	27.5	61.6	35.1
American Elm	16.0	21.9	4.2	0.8	6.8	1.9
Slippery Elm	8.6	11.4	17.0	3.0	31.4	6.9
Basswood	10.4	11.6	12.0	6.0	18.4	7.5
White Ash	9.4	8.5	10.4	12.0	13.6	15.0
Buckeye	7.1	7.5	7.9	4.6	12.8	5.8
Red Oak	2.8	8.5	2.8	11.2	2.4	11.2
Blue Ash	4.8	3.0	2.9	2.6	4.4	2.4
Hackberry	4.1	3.1	20.9	8.5	26.0	13.4
Black Walnut	3.0	5.5	4.0	4.9	7.6	6.6
Bur Oak	1.5	3.5	1.6	5.0	3.5	6.2
Chinquapin Oak	1.2	2.2	0.4	1.4	0.2	1.1
Total	108.1	121.3	121.9	87.5	188.7	113.1

Table 3. Density/acre and frequency (%) of woody species less than 2.6 inch dbh by height or diameter class.

Scientific Name	Common Name	Height Class (<0.6" dbh) <1'	>1'	Total	% Frequency	Diameter Class Density 1" & 2"	Frequency %
Acer saccharum	Sugar maple	368.9	790.5	1159.4	28.1	175.4	33.3
Fraxinus americana	White ash	.	.	.	.	0.8	0.5
Celtis occidentalis	Hackberry	5.3	100.1	105.4	4.2	19.4	10.4
Quercus rubra	Red oak	84.3	15.8	100.1	5.2	3.4	1.6
Tilia americana	Basswood	10.5	.	10.5	1.0	14.3	4.2
Ulmus rubra	Slippery elm	5.3	42.2	47.5	4.7	19.4	7.3
Juglans nigra	Black walnut	.	5.3	5.3	0.5	1.7	1.0
Quercus macrocarpa	Bur oak	10.5	.	10.5	1.0	6.7	3.1
Aesculus glabra	Buckeye	131.8	205.5	333.3	20.3	38.8	15.6
Fraxinus quadrangulata	Blue ash	5.3	36.9	42.2	3.6	11.0	5.2
Ulumus americana	American elm	.	.	.	.	5.1	2.6
Crataegus mollis	Hawthorn	.	10.5	10.5	1.0	5.1	2.6
Asimina triloba	Pawpaw	147.5	442.7	590.2	21.9	192.2	29.2
Quercus muehlenbergii	Chinquapin oak	147.5	58.0	205.5	12.5	5.1	2.6
Gymnocladus dioicus	Kentucky coffee tree	5.3	31.6	36.9	2.1	5.1	2.1
Carya ovata	Shagbark hickory	10.5	.	10.5	1.0	.	.
Carpinus caroliniana	Blue beech	10.5	79.1	89.6	2.6	35.4	5.2
Fraxinus pennsylvanica	Green ash	.	.	.	.	0.8	0.5
Carya cordiformis	Bitternut hickory	.	5.3	5.3	0.5	.	.
Gleditsia triacanthos	Honey locust	.	.	.	.	0.8	0.5
Lindera benzoin	Spicebush	94.8	353.1	447.9	14.6	59.9	10.4
Prunus serotina	Black cherry	.	.	.	.	0.8	0.5
Carya laciniosa	Shellbark hickory	10.5	10.5	21.0	2.1	0.8	0.5
Cornus racemosa	Dogwood	.	21.1	21.1	0.5	1.7	0.5
Prunus virginiana	Chokecherry	63.2	79.1	143.3	0.5	.	.
Zanthoxylum americanum	Prickly ash	.	5.3	5.3	0.5	0.8	0.5
Total				3401.3		604.5	

largest increase was in the 3-6 inch diameter class from 94.0 to 147.8 trees/acre. The stand basal area also increased since 1963, approaching the 1940 level (93.1 to 120.8 square feet per acre). Table 1 shows population characteristics for the 22 major species representing more than 99.5% of the entire stand in terms of basal area and number of trees/acre. The remaining 0.5% consisted of one cottonwood tree of 40.9 inch diameter, previously not recorded, and several small trees whose classifications were questionable.

Sugar maple (Acer saccharum Marsh.) is the by far most abundant species in the stand. The relative basal area of sugar maple has remained the same since 1963 but the absolute values increased from 27.5 to 35.1 square feet reaching the 1940 level (Table 2). Sugar maple is well distributed, occurring in 349 quadrats with a frequency of 90.9%. Sugar Maple also has by far the highest importance value index with 55.7 (Table 1).

In terms of basal area, white ash (Fraxinus americana L.) is the second most important species with a basal area of 15.0 $ft.^2$ or 12.4%. This represents 13.6 trees per acre or 5.9% of the total number of trees. The distribution by diameter class is relatively equal for classes from 3- to 24-inches, but shows a major drop for the 25- to 36-inch class. The average diameter is 14.2 inches. White ash is also well distributed over the forest occurring in 95.8% of the blocks and 61.8% of the quadrats.

The third ranked species in terms of basal area is Hackberry (Celtis occidentalis L.) with a basal area of 13.4 square feet of 11.1% of the total. Its diameter distribution is skewed toward the lower values with the highest frequency in the 3- to 6-inch diameter class. The average diameter of 9.7 inches reflects the large percentage of small trees. Hackberry is distributed well over the forest with a frequency of 96.9% of the blocks and 80.7% of the quadrats.

Fourth in rank order is red oak (Quercus rubra L.) with 11.2 square feet basal area or 9.3%. Red oak has the highest percentage of all species in the 37+ inch diameter class, and the largest average diameter with 29.5 inches. Basswood (Tilia americana L.) and slippery elm (Ulmus rubra Muhl.) are next in terms of basal area, with both species having a large percentage in the lower diameter classes. The number of trees per acre is relatively high for both species resulting in above-average importance values of 14.1 and 19.3, respectively. Slippery elm is dominantly represented among smaller diameter classes with the second highest number of trees in the 3- to 6-inch class (after sugar maple), and very few in the 25- to 36-inch class. The importance value index for slippery elm is third with 19.3 based on the large number of trees and the relative dominance. It is well distributed in the forest and was found in all 96 blocks and in 330 quadrats (85.9% frequency).

These six species represent more than 73% of the basal area of the entire stand.

A graphic representation of the stand density is shown in Figure 1 where number of trees per acre by diameter class is shown for the major species.

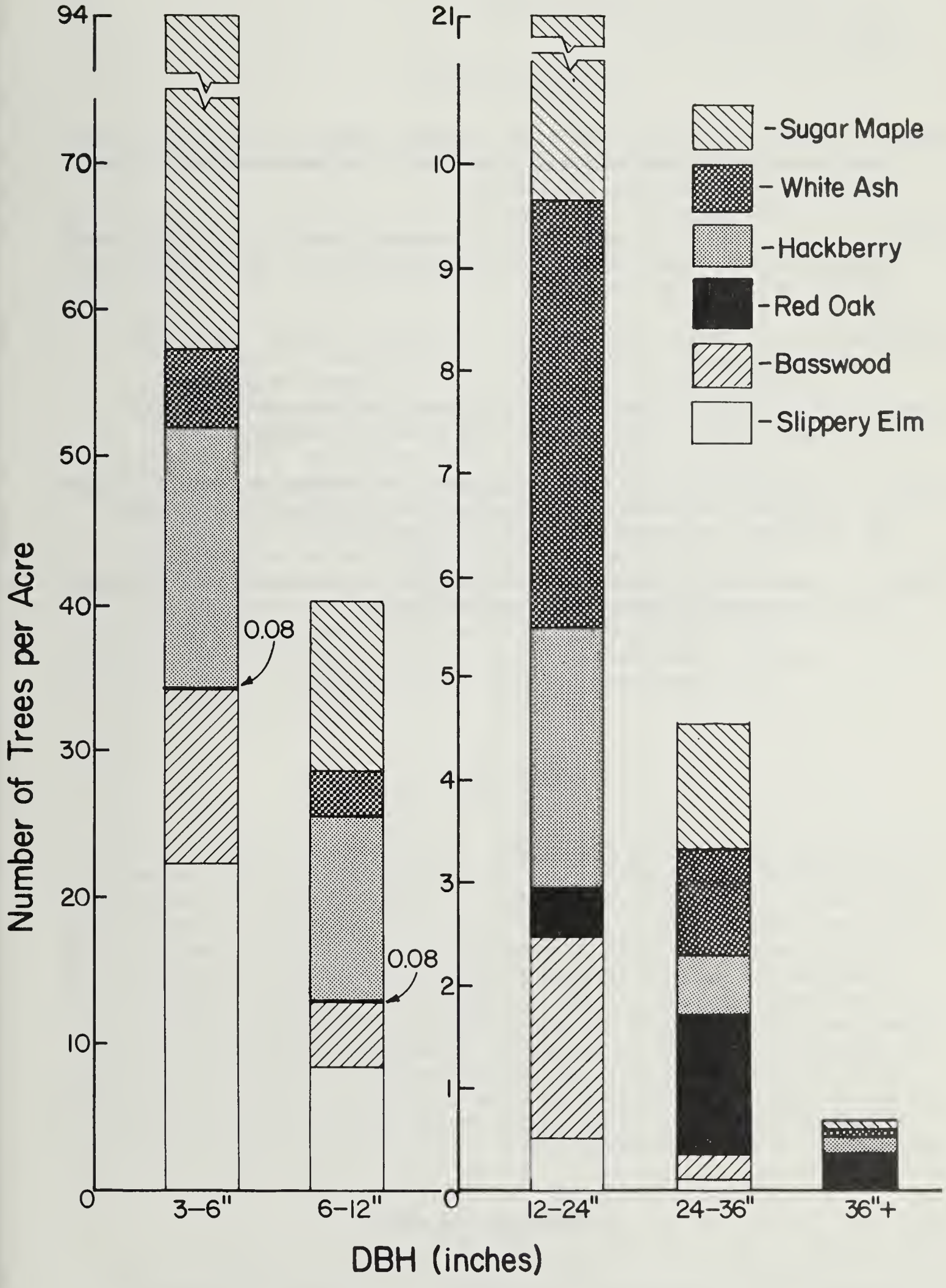
The understory is dominated by sugar maple with 1159.4 seedlings per acre (less than .6 inch diameter) and 175.4 saplings per acre between 0.6 and 2.5 inch diameter (Table 3). Sugar maple seedlings were found in 28% of all plots, saplings in 33% of all plots. Pawpaw is next in density with 590.2 seedlings and 192.2 saplings, follows by spicebush with 447.9 seedlings and 60 saplings per acre. Buckeye and chinquapin oak also show a relative high density in the seedling stage. Other tree species have a considerable lower number of seedlings and saplings.

The most remarkable changes in stand composition since the 1963 inventory are the increases in number of trees per acre and basal area per acre. Sugar maple increased from 27.5 square feet basal area in 1963 to 35.1, with a shift toward smaller diameter classes and an increase in number of trees/acre from 37.8 to 61.6 (Table 2). Slippery elm more than doubled in basal area from 3.0 to 6.9 square feet and increased its number of trees/acre from 18.0 to 31.4. American elm shows a small increase from 0.8 ft.^{2} to 1.9 ft.^{2}. Hackberry also shows a remarkable increase in basal area and a corresponding shift toward larger diameter classes. Bur oak shows an increased basal area, but its diameter distribution is shifting toward the smaller diameter classes as the old large trees die. The average diameter decreased from 23.9 inches to 18.0 inches is due to the mortality of the larger diameter classes and increase number of the smaller individuals in the smaller classes. The number of large trees increased significantly since the last inventory. A total of 22 trees of more than 36.5 inch diameter were measured in 1963 whereas in 1976 47 trees were recorded.

The decline in basal area and number of trees per acre resulting from the high mortality due to Dutch elm disease was reversed during the last 13 years, with areas once occupied by american elm now occupied by a variety of species. Slippery elm gained most in relative terms with an increase in importance value from 15.3 to 19.3. However, sugar maple showed the largest increase in absolute numbers and the third largest in relative terms after slippery elm and black walnut. Pawpaw invaded the spaces previously occupied by elms increasing in number of trees per acre from 9.1 in 1963 to 20.8 in 1976.

It seems remarkable that the relative species composition of the forest was not significantly altered due to a natural catastrophy such as the Dutch elm disease but that most species simply increased in number of trees and basal area to occupy the available niche and maintain their standing in the forest.

In the present stand sugar maple is the leading dominant with 29% of the total number of trees. It is likely that it will maintain its dominant position in the future because of its importance in the seedling stage (34% of total individuals) and in the sapling stage (29% of total individuals).


Number of Trees per Acre
94
70
60
50
40
30
20
10
0
21
10
9
8
7
6
5
4
3
2
1
0
0.08
0.08
3–6"
6–12"
12–24"
24–36"
36"+
DBH (inches)
Sugar Maple
White Ash
Hackberry
Red Oak
Basswood
Slippery Elm

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HELMINTH PARASITES FROM ILLINOIS WILD TURKEYS

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Abstract: Viscera from 69 wild turkeys (Meleagris gallopavo silvestris) collected from Jackson, Union and Alexander counties, Illinois, were examined for helminth and coccidian parasites. Eight species of parasites were found, all in the alimentary tract. Nematode parasites Heterakis gallinarum, Ascaridia galli and Ascaridia dissimilis were found in 13.2%, 27.9% and 48.5% respectively of all birds examined. Infection rates of Ascaridia galli were higher in juveniles than in adults. Three species of cestodes, Raillietina williamsi, Metroliasthes lucida and Hymenolepis sp., were recovered from 41.1%, 27.9% and 1.4% respectively of the birds examined. Trematodes of the genus Cotylurus were recovered from 2.9% of the birds.

INTRODUCTION

Management of the wild turkey (Meleagris gallopavo silvestris) population in Illinois is dependent, in part, on understanding the role of parasitism as a limiting factor in these game birds. Wild turkeys have been reestablished at densities sufficient to support hunting in Illinois only since 1970 and little is known of their parasites. Surveys of parasites in wild turkeys have been made in several southeastern states (Prestwood 1968, Maxfield et al. 1963). Although these studies were primarily concerned with determining the kinds of parasites present and their geographic distribution, Prestwood et al. (1973) considered parasites and disease to be responsible for a large proportion of the 50-60% annual mortality not attributed to hunting. This is a report of a survey of parasites in Illinois turkeys which must be preliminary to determining the pathogenic effects of the parasites.

MATERIALS AND METHODS

Viscera of 69 male wild turkeys were collected at check stations

maintained by the Illinois Department of Conservation during the spring hunting seasons in 1972 and 1973. All birds brought to the check stations had been killed in Alexander, Jackson and Union counties. The age, weight and location of kill were recorded for each bird.

Viscera collected were examined immediately for parasites. The alimentary canals were opened and the contents flushed with water into white enamel pans and examined for parasites. Hearts and livers were opened with scissors and the tissue examined for parasites. Cestodes and nematodes were fixed in labeled vials of A.F.A. Fecal samples (1973 only) were collected from the lower alimentary region. Two grams of feces was placed in approximately 50 ml. of 2.5% potassium dichromate solution in labeled 1-pint plastic jars. The lids of the jars were not tightened so that sporulating oocysts present would be allowed air.

Nematodes were cleared with lacto-phenol on glass slides and identified. Confirmation of the identification of the nematodes was given by Dr. Ralph Lichtenfelds of the Animal Parasitology Institute, Agricultural Research Center, USDA, Beltsville, Maryland. Scoleces and proglottids of representative cestodes were fixed with acetocarmine, cleared, and mounted on glass slides. Identification of the cestodes was based on Williams (1931), Wardle and McLeod (1952) and Yamaguti (1961). Fecal samples for protozoan examination were kept for two weeks after collection at room temperature to permit sporulation. Oocysts were isolated from the feces by using a modified sugar floatation method (Cable 1966), and identified to family (Levine 1961).

RESULTS

Seven species of helminth parasites were found in the lower alimentary tract of 69 turkeys examined in 1972 and 1973 (Table 1). No parasites were found in the esophagus, heart, liver or crop. Juvenile and adult infection rates are compared in Table 2.

Three species of nematodes were recovered from the birds. Heterakis gallinarum was removed from the ceca of nine of 68 turkeys. A range of one to 13 adult parasites was found in the birds with a mean of 6.6. In two birds, approximately 50 juveniles of H. gallinarum were found. Ascaridia galli was found in 19 out of 68 wild turkeys. Birds infected with A. galli harbored from one to 46 worms, with an average of 6.9. Ascaridia dissimilis was found in the intestine of 33 of 68 wild turkeys. A mean of 11.2 and a range of one to 40 parasites per bird was found. Three species of cestodes were found infecting Illinois wild turkeys. Raillietina williamsi and Metroliasthes lucida occurred frequently, 41% and 27.9% respectively. In some cases, combined infections were so heavy that the intestinal lumen appeared to be blocked. Several specimens of a third cestode, Hymenolepis sp., were found in a single adult turkey from Alexander County. Seven trematodes of the genus Cotylurus were recovered from the intestine of a turkey in 1972 and 10 were found in another bird

TABLE 1. Gastrointestinal parasites from wild turkeys shot in southern Illinois in 1972 and 1973.

Parasite	Alexander County		Jackson County		Union County		Total	
	No. Examined	% Positive	No. Examined	% Positive	No. Examined	% Positive	No. Examined	% Positive
Nematoda								
Heterakis gallinarum	22	13.6	21	14.3	25	12.0	68	13.2
Ascaridia galli	22	40.9	21	23.8	25	20.0	68	27.9
Ascaridia dissimilis	22	63.6	21	52.3	25	32.0	68	48.5
Cestoda								
Raillietina williamsi	22	77.3	21	9.5	25	36.0	68	41.1
Metroliasthes lucida	22	18.1	21	14.3	25	48.0	68	27.9
Hymenolepis sp.	22	4.5	21	--	25	--	68	1.4
Trematoda								
Cotylurus sp.	22	--	21	9.5	25	--	68	2.9

TABLE 2. Percent adult and juvenile turkeys infected with gastrointestinal parasites in 1972 and 1973.

Parasite	Adults		Juveniles	
	No. Infected	% Positive	No. Infected	% Positive
Nematoda				
Heterakis gallinarum	6	13.0	3	13.6
Ascaridia galli	11	23.9	8	36.3
Ascaridia dissimilis	23	50.0	10	45.5
Cestoda				
Raillietina williamsi	18	39.1	10	45.4
Metroliasthes lucida	14	30.4	5	22.7
Hymenolepis sp.	1	2.1	--	--
Trematoda				
Cotylurus sp.	2	4.3	--	--

in 1973. Both turkeys were adults killed in Jackson County. Oocysts of *Eimeria* were recovered from feces of three of 31 (10%) turkeys.

DISCUSSION

Illinois wild turkeys had a lower rate of parasitic infections than reported for wild turkeys in other areas of the United States (Maxfield et al. 1963, Prestwood 1968). Illinois turkeys are well dispersed and densities may be lower than other populations studied. This factor would reduce the chance of food and water contamination by parasite ova passed in feces as well as reduce the chance of intermediate hosts of some parasites becoming infected. Other reasons for lower infections in Illinois birds may be due to climatic differences in the study areas, such as average annual temperature and amounts of rainfall. *Ascaridia galli* was the only parasite found more frequently in Illinois turkeys than in birds of other study areas. This nematode is common in domestic turkeys and chickens, and a high incidence of this parasite in wild turkeys may be attributed to domestic fowl contaminating parts of the turkey range with ova passed in feces.

Parasitic infections were similar in turkeys from the three Illinois counties except that trematodes were found only in Jackson County and the single *Hymenolepis* sp. found in Alexander County. The three counties are adjacent and the turkey population is essentially

continuous across them. Differences in parasite fauna in the birds are expected to be slight although minimal variations may exist due to local habitat variation or concentrations of reservoir hosts such as domestic fowl.

Cecal infections with Heterakis gallinarum totaled 13.2% of Illinois turkeys examined. This was a much lower rate than reported by Maxfield (62%) in 1963 and Prestwood (97%) in 1968. This parasite may be significant in turkey mortality because the protozoan Histomonas meleagridis, which is responsible for blackhead disease in turkeys, is transmitted from bird to bird through the ingested ova of this nematode (Prestwood et al. 1973). Blackhead could cause high mortality in the Illinois wild turkey population since the domestic chicken and bobwhite quail, common carriers of blackhead disease, share parts of the turkey range.

The pathogenicity of the other helminths found is relatively unknown. Some of these species found in large numbers can reduce the general health of the turkeys and cause weight loss (Wehr 1952). The nematodes A. galli and A. dissimilis and cestodes R. williamsi and M. lucida, which were found in large numbers, could be responsible for mortality if turkeys were stressed by severe weather.

We found distinctly higher infection rates in juveniles for only one of the seven helminth species recovered, Ascaridia galli. Infection rates were actually higher in adult birds for Ascaridia dissimilis, Metroliasthes lucida, Hymenolepis sp. and Cotylurus. It should be noted, however, that 68% of the birds examined were adults.

ACKNOWLEDGMENT

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INHERITANCE OF FIVE NEW CHARACTERS IN COLLINSIA HETROPHYLLA

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ABSTRACT. Five new genetic characters of Collinsia heterophylla Buist. (2n = 14) are reported: (1) recessive cotyledon lethal, le; (2) replicate vernation, re; (3) rimmed leaf, ri, displaying raised peripheral veins of the blade; (4) dentate, denticulate, crenate, and crenulated leaf margin controlled by four alleles of the Lm locus; and (5) displaced bud, db, displaying the fusion of the basal region of the lateral branches with the main stem. Physiological and morphogenetic aspects of the lethal, leaf margin, and displaced bud phenotype are briefly discussed.

For studies on genetic homologies among the 21 species of the genus Collinsia Nutt. (Scrophulariaceae) a large number of known gene loci in C. heterophylla - the most variable species of the genus - is required.

This paper adds five genetic characters to the list of 76 previously reported (Hiorth, 1930, 1931; Rai and Garber, 1960; Goršič, 1957, 1973). The seed used in this study were of the same origin as the seed used in previous studies (Goršič, 1973, 1974). Methods of cultivation and hybridization of Collinsia plants have been reported by Goršič (1957).

OBSERVATIONS AND INTERPRETATIONS

One trait reported in this paper is scored in the cotyledon stage of seedlings, three traits concern the development and morphology of leaves, and one trait represents the displacement of axillary buds.

Lethal, le (Tab. 1, Fig. 1). After emergence from the soil, the cotyledons of the homozygous le/le plants expand only to the size of about one third of the cotyledons of the wild-type plants. At the age of three weeks the cup-shaped, green cotyledons discolor brown, and the seedlings wilt and die exhibiting no plumule.

Replicate, re (Tab. 1, Figs. 2, 3). C. heterophylla has a decussate leaf arrangement. Plants of the replicate phenotype have one leaf of each pair folded backward (adaxially) in the bud. The folded leaves alternate with the non-folded leaves in two rows on one side of the stem. The replicate trait is not expressed at the lowermost nodes. The irregular folding of bracts (3 - 7 per node) of the inflorescence, ob-

served in the replicate (re/re), and in the wild-type plants, is not controlled by the re gene.

Rimmed leaf, ri (Tab. 1, Figs. 5, 6, 7). The leaves of the homozygous ri/ri plants have a rim on the upper (adaxial) side along the margin of the blade. The rim, being slightly raised above the surface of the leaf, is produced by the proliferation of the cells of the bundle sheath of the veins. The terminal branches of the peripheral veins are primarily affected. The ri, Lf (leaf form, Goršič, 1973), sn (spotted necrosis, Goršič, 1973), and Lm (leaf margin, see below) genes appear to be closely linked (Tab. 3).

Table 1. Segregation of backcrosses (BC) and F_2 generations for four characters of C. heterophylla

Character	Gene	No. of cultures	Segregation (*)	No. of dominants	No. of recessives	Expected No. of reces.	Chi-square value
lethal	le	8	F_2	93	28	30.25	0.222
replicate	re	46	F_2	448	144	148	0.143
		5	BC	43	43	43	--
rimmed leaf	ri	6	F_2	77	26	25.75	--
		2	BC	26	22	24	0.332
displaced bud	db	10	F_2	117	30	36.75	1.651

(*) Expected ratios: BC = 1:1, F_2 = 3:1

Leaf margin, Lm (Tab. 2, Figs. 4, 9, 10). The leaves of C. heterophylla vary morphologically in (1) the composition (controlled by D and Fi alleles, Hiorth, 1930; Goršič, 1957), (2) the shape of the blade (controlled by Lf alleles, Goršič, 1973), and (3) the nature of the leaf margin.

Four pure-breeding lines have been identified for the leaf margin, namely: dentate, denticulate, crenate, and crenulated (Fig. 9). On the basis of the phenotypic ratios obtained in the progenies of the hybrids between these pure-breeding lines (Tab. 2), a single locus, having four alleles, is postulated to control the leaf margin phenotypes; the four alleles being: Lm^d (dentate), Lm^l (denticulate), Lm^c (crenate), and Lm^r (crenulated, shallow crenate). These alleles interact in the hybrids producing intermediate phenotypes (Fig. 10). Some reciprocal crosses do not produce identical phenotypes (compare Lm^dLm^c and Lm^cLm^d leaves in Fig. 10). Plants of the pure-breeding (homozygous) lines having leaves with a conspicuously different margin are easy to identify but, in segregating populations composed of three or four genotypic classes, to match with certitude all observed phenotypes with the corresponding genotype is well-nigh impossible. The ri (rimmed leaf) gene which is closely linked with the Lm locus (Tab. 3) can be used in the hybridization experiments to facilitate the scoring of the leaf margin phenotypes of

Table 2. Segregation of F_2 generations and backcrosses (BC) of hybrids involving leaf margin alleles: Lm^d, Lm^l, Lm^c, and Lm^r

Parental genotype	No. of cultures	Segregation	Progeny: Homozygotes	Heterozygotes	Heterozygotes	Homozygotes	Expected ratio	Chi-square value
Lm^dLm^c	19	F_2	91	199	--	85	1:2:1	1.548
Lm^dLm^r	2	F_2	7	20	--	6	1:2:1	1.416
Lm^lLm^c	3	F_2	15	40	--	17	1:2:1	0.999
Lm^lLm^r	2	F_2	10	31	--	11	1:2:1	1.960
Lm^cLm^d x Lm^cLm^c	1	BC	8	7	--	--	1:1	--
Lm^cLm^d x Lm^dLm^d	2	BC	26	26	--	--	1:1	--
Lm^cLm^d x Lm^lLm^l	2	BC	--	27	31	--	1:1	0.274
Lm^cLm^l x Lm^lLm^l	1	BC	6	6	--	--	1:1	--
Lm^cLm^r x Lm^dLm^d	1	BC	--	12	12	--	1:1	--
Lm^dLm^l x Lm^rLm^r	1	BC	--	9	8	--	1:1	--
Lm^dLm^r x Lm^dLm^d	2	BC	22	21	--	--	1:1	--
Lm^lLm^r x Lm^cLm^c	1	BC	--	4	4	--	1:1	--
Lm^rLm^r x Lm^cLm^d	2	BC	--	10	10	--	1:1	--

Table 3. Pairs of genes showing significant deviation from independent segregation ratios

Genes	Segregation*	AB	Ab	aB	ab	Total
Lm^c - ri	F_2	50	0	2	20	72
Lm^c - ri	BC	26	0	0	21	47
Lf^e - Lm^d	F_2	23	0	0	9	32
Lf^e - sn	F_2	19	2	3	8	32
Lm^c - sn	F_2	20	2	3	7	32

* Expected ratios: F_2 = 9:3:3:1, BC = 1:1:1:1

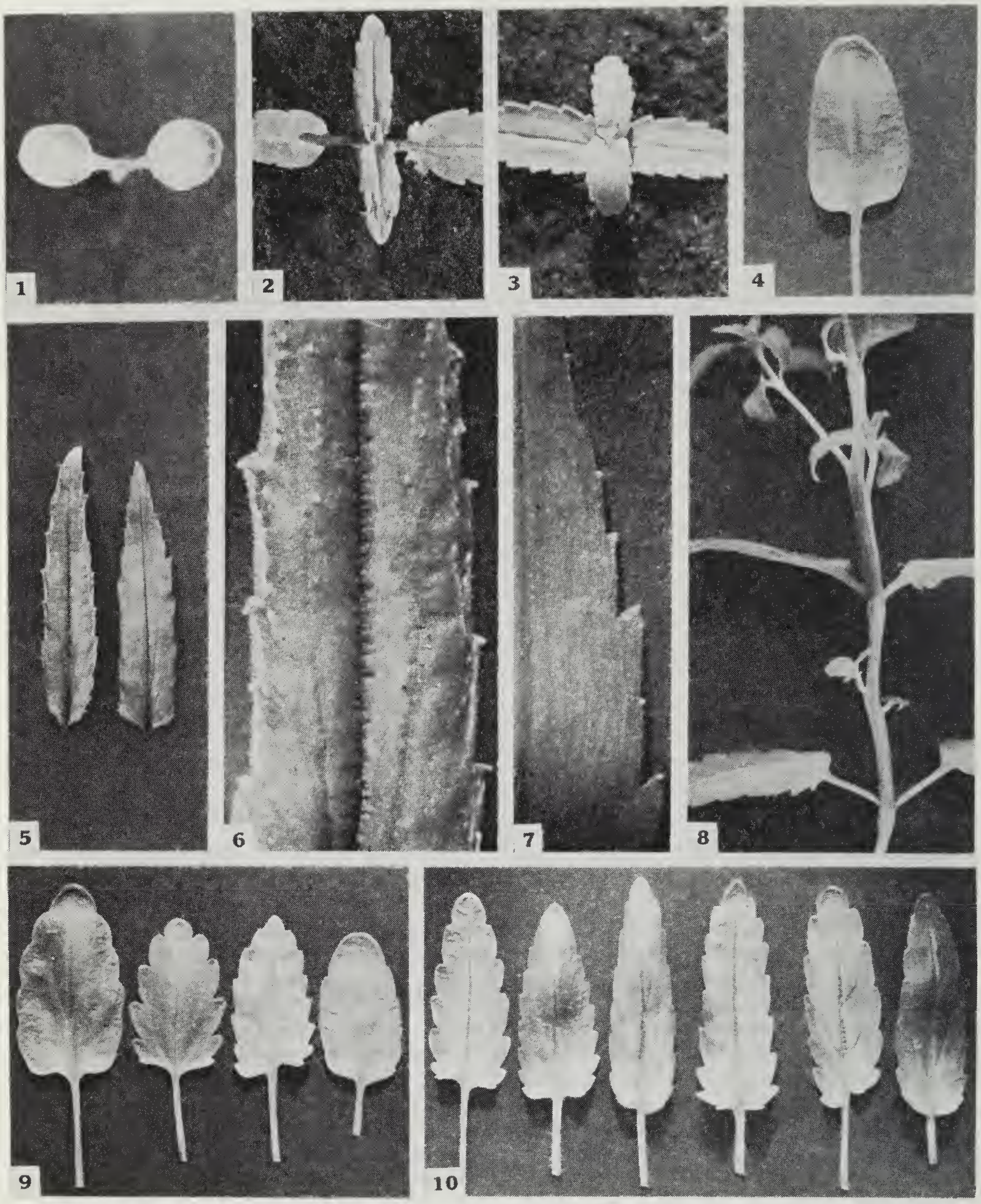

PLATE 1. Gene expression in Collinsia heterophylla. FIGURE 1. Cotyledon lethal, le. FIGURE 2. Replicate, re. FIGURE 3. Non-replicate (wild-type), Re. FIGURE 4. Nonserrate (zahnlos), z. FIGURE 5. Rimmed leaf, ri (left), and wild-type (right). FIGURE 6. A close-up of a rimmed (ri) leaf. FIGURE 7. A close-up of a wild-type (non-rimmed) leaf. FIGURE 8. Displaced axillary bud,

sodium playing the major role. Similar results have been reported for several species of Ephemeroptera, Homopter and Odonata (Florkin and Jeuniaux 1974; Sutcliffe 1963), Orthoptera and Isoptera (Duchateau et al. 1953; Jeuniaux 1971; Wyatt 1961), and a labidurid Dermapteran (Leader and Bedford 1972).

The results also indicate that sodium and chloride are the inorganic ions present in the greatest concentration. This has been reported for several additional exopterygote species (Jeuniaux 1971) as well. This differs, however, from results reported for several endopterygote species including the Mecoptera, Neuroptera, Trichoptera and Diptera (Duchateau et al. 1953; Florkin and Jeuniaux 1974). In these

TABLE 1. The inorganic ion composition of the hemolymph of Labia minor. Ion concentrations expressed in mM/liter of hemolymph.

Total Osmotic Pressure	232.7
Cations:	
sodium	104.5
potassium	18.2
calcium	16.8
magnesium	7.3
Total	136.8
Anions:	
chloride	91.8
phosphate	6.3
Total	98.1

endopterygotes, sodium is the principle cation, but the chloride ion concentration is greatly reduced and is partially replaced by a significantly higher amino acid concentration. Sodium is replaced by magnesium as the dominant hemolymph cation in some phasmatid Orthopterans (Jeuniaux 1971; Wyatt 1961). The effect of cations and chloride on osmotic pressure is greatly reduced in several species of Lepidoptera, Coleoptera and Hymenoptera, with organic molecules having the greatest osmotic effect (Duchateau et al. 1953; Ikan and Ishay 1973; Ishay 1975; Jungreis et al. 1973; Levenbook and Hollis 1961).

Results such as this have led to tentative conclusions concerning the biochemical evolution of insects and other arthropods. Sutcliffe (1963) has proposed that, in general, the more primitive insects (apterygotes and exopterygotes) tend to have hemolymph characterized by high concentrations of inorganic ions and low concentrations of organic compounds, whereas the more advanced insect groups (endopterygotes) show a reduced inorganic ion concentration with a concomitant increase in organic substances such as amino acids. The hemolymph of other arthropod groups such as Onycophora, Diplopoda, Chilopoda, arachnids and terrestrial isopods, is characterized by a high concentration of sodium and chloride ions (Alikhan 1973; Bedford and Leader 1975; Bowerman 1976; Campaglia 1976; Jennifer and Leader 1975; Jeuniaux 1971; Naire and Prabhu 1971). This suggests a closer taxonomic relationship between these arthropods and the apterygote and exopterygote insects than with the endopterygote insects. The results obtained in this study show the electrolyte composition pattern of the hemolymph of L. minor (Labiidae) to be very similar to the general inorganic ion hemolymph composition reported for other earwigs (Leader and Bedford 1972), and that this pattern is more similar to the concentrations found in non-insectan arthropods and other exopterygotes than it is to the more advanced endopterygote insects. In addition, the concentration of the dominant sodium and chloride ions in this species, 104.5 and 91.8 mM/l respectively, varied somewhat from that reported for a labidurid (193, 80) earwig (Florkin and Jeuniaux 1974; Leader and Bedford 1972) and a forficulid earwig (96, 80). This supports the classification of Labia minor as a separate family, Labiidae. Additional hemolymph studies on more species will further clarify the phylogenetic relationships of the Insecta and the Arthropoda as a whole.

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AGRICULTURAL PESTICIDES IN WILD TURKEYS IN SOUTHERN ILLINOIS

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Abstract: Adipose tissue from 55 male turkeys, killed during the 1974 hunting season in southern Illinois, was analyzed for pesticide concentrations by gas/liquid chromatography. Twelve pesticides were identified in the samples with only four, total DDT, heptachlor epoxide, toxaphene, and linuron, present in all samples. Concentrations ranged from 0.22 ppm to 0.88 ppm.

The wild turkey (Meleagris gallapavo, Linn.) is an important gamebird for a limited number of Illinois hunters. Management of the turkey requires an understanding of factors that may influence their health and productivity. As in other galliform birds, pesticides may influence behavior and thereby survival (Baxter et. al. 1969, Dahlgren and Linder 1971, Dahlgren and Linder 1974, McEwen and Brown 1966). The probability that turkeys will be exposed to some pesticide is high since the wild turkey has a varied diet which includes mast, fruits, cultivated crops, grasses, and a multitude of invertebrates (Edminster 1954). This is a report of a survey of pesticides in the adipose tissue of wild turkeys harvested in southern Illinois in 1974.

Data in this paper are from an M.S. thesis, Department of Zoology, Eastern Illinois University. The study was supported in part by Illinois Department of Conservation Federal Aid Project W-63-R. Dr. J. Ellis, Chemistry Department, Eastern Illinois University, assisted with the chemical instrumentation and extraction procedures.

MATERIALS AND METHODS

Turkeys were killed by hunters in Jackson, Union, Alexander, and Pope Counties in southern Illinois during two 5-day hunting seasons in April, 1974. At check stations in each county, fat samples were removed from either the interfurcular fat depot or the "breast sponge." Fat samples were pooled by age class and county into ten groups. Extraction procedures described in the Pesticides Analytical Manual, Volume III (U.S. Dept. Health, Education, and Welfare 1970) were followed verbatum except that 15-20 gm of adipose tissue were required to produce 1.5-2.5 gm of fat. The fat obtained was accurately weighed and all was used. A reagent control was prepared after each extraction by following all extraction procedures without the adipose tissue.

Extracts were analyzed with a Varian Aerograph, Series 2800 gas chromatograph with an electron capture detector, and an A-25 recorder. Nitrogen, the carrier gas, was allowed to flow at a column head pressure of 58 psi. The column was 4 x 1830 mm stainless steel, and packed with 3% QF-1 with a solid support of 80/100 mesh Chromosorb W, acid washed and treated with dimethyl dichlorosilane. Injector, column, and detector temperatures were 200°, 200°, and 225° C, respectively.

Pesticide standards were obtained from the U.S. Environmental Protection Agency's Toxic Substances Effects Laboratory, Research Triangle Park, North Carolina. Standard solutions of 1.0 ppm were prepared, injected into the gas chromatograph, and retention times noted. Mixtures of the standard solutions were made to determine retention times of pesticide combinations. Identification of pesticides in fat samples was made by comparing retention times with peaks of standard mixtures. Pesticides were quantified using the disc integrater on the recorder and comparing integrations with those of 1.0 ppm solutions.

RESULTS

The 1974 hunting season resulted in a harvest of 55 male turkeys, 33 adults and 22 juveniles. Adipose tissue was collected from 54 birds. One bird (J-14) was noted to have a noticeably small gizzard and liver, overly large testes for a juvenile, large quantities of yellow unvascularized fat, and brown legs. The bird was believed to be domestic; its fat was analyzed separately from other juveniles from Jackson County.

The turkeys sampled contained 13 identified pesticides (Table 1). No residues of malathion, methoxychlor, alachlor, bromacil, propachlor, 2, 4-D and 2, 4, 5-T were detected. Most pesticides occurred at less than 0.30 ppm and none occurred at greater than 0.88 ppm (simazine). Heptachlor epoxide, toxaphene, linuron, and DDT and its isomers, were present in all samples. Toxaphene (0.12 to 0.82 ppm) and total DDT (0.12 to 0.83 ppm) showed the heaviest concentrations while Heptachlor epoxide and linuron were in trace amounts (< 0.10 ppm) and never occurred in concentrations greater than 0.16 ppm.

TABLE 1. Pesticide concentrations (ppm) in the adipose tissue of wild turkeys harvested in 1974 in southern Illinois

Pesticide	Jackson County		Union County				Alexander County		Pope County	J-14
	Adult	Juvenile	South Adult	North Adult	South Juvenile	North Juvenile	Adult	Juvenile		
	10[a]	3[a]	4[a]	8[a]	3[a]	4[a]	8[a]	8[a]	5[a]	1[a]
Aldrin	--	--	--	--	--	--	--	--	--	.55
Atrazine	--	--	--	--	--	--	.61	.50	.50	--
Chlordane	--	--	--	.19	--	.19	.60	.47	.12	--
Total DDT	.41	.30	.61	.83	.37	.72	.29	.24	.71	.12
Dieldrin	.36	.07	.14	.38	.14	.18	--	--	.23	.05
Endrin	--	--	--	--	--	--	.59	.45	--	--
Heptachlor epoxide	.14	.09	.10	.16	.08	.10	.10	.09	.13	.09
Lindane	.09	.07	.13	.11	.04	.09	.11	.02	--	--
Linuron	.12	.09	.14	.12	.13	.10	.10	.08	.08	.06
Silvex	--	--	.20	.24	.10	.13	.49	.28	.30	--
Simazine	.27	--	--	--	--	--	--	--	--	.88
Toxaphene	.51	.37	.58	.68	.39	.56	.43	.29	.82	.12
Trifluralin	.12	--	--	--	--	--	--	--	--	--
TOTAL	2.22	1.19	2.10	2.91	1.45	2.27	3.52	2.62	3.09	2.07
County Mean	0.26				0.46					

[a]Number of birds in sample

Differences in pesticide concentrations were evident between counties and between age groups. Pope County had the heaviest concentration (0.62 ppm) per bird. Atrazine and endrin were noted only in Alexander County and trifluralin and simazine only in Jackson County. Juvenile birds, with few exceptions had the same pesticides as an adult but concentrations were usually less. The sample from J-14 was the only one with aldrin and, it contained more simazine and less total DDT and toxaphene than other birds.

Unidentified pesticides were present in four of the 10 samples. Jackson County juveniles contained 19.2%, unknown, south Union County juveniles 2.4%, Alexander County juveniles 3.8%, and the J-14 sample 23.2%.

The percentage of fat in the adipose tissue, determined during the extraction procedures, ranged from 18.2% in Pope County to 5.8% for the northern Union County juveniles. The J-14 sample was an exception; 65% of the adipose tissue was fat. There was no correlation ($P > 0.10$) between fat concentration or average body weight and the total pesticide concentrations in the groups using Spearman's correlation test (Langley 1971).

DISCUSSION

The pesticides found in fat samples of wild turkeys were within the tolerance levels set for poultry products by the U.S. Environmental Protection Agency with the exception of the dieldrin in adults of Jackson County and north Union County. The concentrations of dieldrin in these two samples slightly exceed the 0.30 ppm tolerance level. According to W. H. Stickel (Patuxent Wildlife Research Center, personal communication) these tolerance levels offer much latitude and no ill effects can be expected from consumption of these birds. Furthermore, pesticides reported for Illinois wild turkeys are from adipose tissue rather than muscle tissue which is usually consumed.

The pesticides found in the Illinois turkeys are indicative of those used in agricultural practices in southern Illinois (Steve Moore III, Illinois Natural History Survey, personal communication, and Dr. R. Hill, Illinois Department of Agriculture, Regional Diagnostic Laboratory, Centralia, Illinois, personal communication). According to Dr. Moore, dieldrin is used in orchards and could result from isomerization of aldrin used to treat row crops. Heptachlor epoxide, chlordane, toxaphene, and methozychlor are applied to grain crops. Further, he said that although DDT is not now being used, it could be expected from its past usage on orchards and row crops. Dr. Hill has detected atrazine, simazine, alachlor, linuron, 2, 4-D, 2, 4, 5-T, trifluralin, and propachlor in plants and soils from Jackson, Union, Alexander, and Pope Counties. These herbicides are used to control vegetation in agriculture and on road, pipeline and powerline rights-of-way.

Turkeys range into cultivated fields and are exposed to agricultural pesticides directly, or chlorinated hydrocarbons could be transported from farm to forest by runoff. Pesticides applied within the forest might also reach the turkeys directly. Methoxychlor, malathion, lindane, and chlordane are used for control of foliage feeders such as lepidopteran larvae; dieldrin, aldrin and occassionally DDT are applied to control soil larvae such as some coleopteran larvae; and 2, 4-D 2, 4, 5-T, simazine, atrazine, trifluralin, and bromacil are used to control vegetation (K. F. Ford, Commonwealth Associates Inc., personal communication). District rangers report the use of malathion in Jackson County at the rate of 1.25 lbs/acre to control the alfalfa weevil; 2, 4-D was used in Pope, Union, and Jackson Counties at the rate of 4 lbs/acre to retard revegetation; and simazine was used in Jackson County for vegetation control. (R. A. Tucker, J. Newcomb, and G. H. Lyon Jr., District Rangers, Vienna, Jonesboro, and Murphysboro Ranger Districts, respectively, personal communication).

There are no published data on pesticides in wild turkey populations; however, some work has been done with domestic turkeys (Anderson et al. 1951, Marsden and Bird 1947) and other wild galliform birds. Domestic turkeys eating meal containing 0.075% (750 ppm) DDT or more showed depressed growth and even death (Marsden and Bird 1947). This is a concentrated amount of DDT; it is unlikely that wild turkeys would be exposed to similar concentrations. Dieldrin, tested on sharp-tailed grouse in the field, was found to adversely affect the behavior of breeding males receiving 25 mg pesticide/kg of body weight (McEwen and Brown 1966). Nusz et al. (1976) tested bobwhites with dieldrin and found they gained less weight than undosed birds. Toxaphene has been found by Genelly and Rudd (1956) to depress egg production, fertility, and hatchability if given to pheasants in concentrations of 300 ppm or more.

Numerous workers reported that egg production, egg weight, clutch size, number of clutches, fertility, and hatchability of gallinaceous birds was unaffected by most chlorinated hydrocarbons (Dahlgren and Linder 1974, Davison and Sell 1972, Lillie et al. 1973, Messick et al. 1974, and Whitehead et al. 1972). Dahlgren and Linder (1974) noted that the progeny of cock and hen pheasants fed dieldrin showed aberrant behavior through the third generation. We can draw no conclusions about the effects of pesticides in Illinois wild turkeys.

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GLACIAL LOESS--IS IT REALLY GLACIAL?*

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ABSTRACT - Glacial-non-glacial climatic shifts exhibit an episodic or square-wave behavior, while the growth-decay response of glacial ice approximates a normal curve. If this model is realistic, Laurentide melt-water discharge and alluviation along proglacial drainageways peaked several thousand years after the last major Wisconsinan climatic shift from dominantly glacial to dominantly non-glacial regimes. This also implies that the principal period of wind erosion of floodplain deposits (and loess accumulation) occurred during climatic episodes that were distinctly non-glacial.

Glacial loess primarily consists of moderately well-sorted, unconsolidated, locally laminated blankets of silt. Although dominant (40% to 50%) grain size is 0.01 mm to 0.05 mm, deposits generally are accompanied by significant clayey (5% to 30%) and sandy (5% to 10%) fractions (Pecsi, 1968). Typically, glacial loess is porous and permeable, yellow to buff, and is exposed in nearly vertical cliffs. In the nation's midsection late Wisconsin loess occurs in two convergent belts: One deposit thins eastward from Nebraska and Kansas through Iowa, Missouri, Wisconsin, Illinois, Indiana and into southern Ohio. The second belt is east of the Mississippi River and south of the Ohio River from Mississippi through western Tennessee and Kentucky.

Loess units of the Great Plains and South are eolian in origin with the bulk of loess derived by wind erosion of glacial outwash floodplain and channel bar deposits (Flint, 1971, p. 250). In Nebraska and adjacent areas, however, this mechanism may have played a secondary role to deflation in the Sand Hills of west-central Nebraska (Lugn, 1968). Additionally, in the narrow periglacial zone adjacent to the Laurentide ice sheet, frost heaving and churning of soils probably provided minor sources of silt for subsequent redeposition as loess (Davies, 1972).

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*The substance of this paper was presented at the 1976 Annual Meeting of the Illinois State Academy of Science. At the time the author was a Visiting Associate Professor in the Department of Geography, University of Illinois at Urbana-Champaign.

Loess deposits in the Central United States are traditionally described as glacial--a designation that some construe to indicate deposition during periods of severe climate. Although most late Wisconsinan loess was deposited in close association in time and place with extensive continental glaciation, there are reasons to believe that the bulk of loess accumulated during climatic episodes that were distinctly non-glacial.

LOESS AND CLIMATE

A simple glacier-climate model proposed by Bryson and Wendland (1967) sheds some light on the general relationship between loess deposition and climatic regimes (Figure 1). The Bryson-Wendland model depicts the large scale climatic behavior during the Quaternary as a square wave, i.e., a sequence of glacial and non-glacial episodes punctuated by abrupt shifts between episodes. This abrupt change nature of Quaternary climates is confirmed by studies of pollen stratigraphy and by other paleoenvironmental indices (Bryson, 1974). Prevailing atmospheric circulation patterns favor glacial expansion (positive mass balance) during glacial climatic episodes and glacial recession (negative mass balance) during non-glacial climatic episodes. This model, however, is concerned with prevailing climatic conditions, and thus does not exclude periods of ablation during glacial episodes and periods of glacial growth during non-glacial episodes.

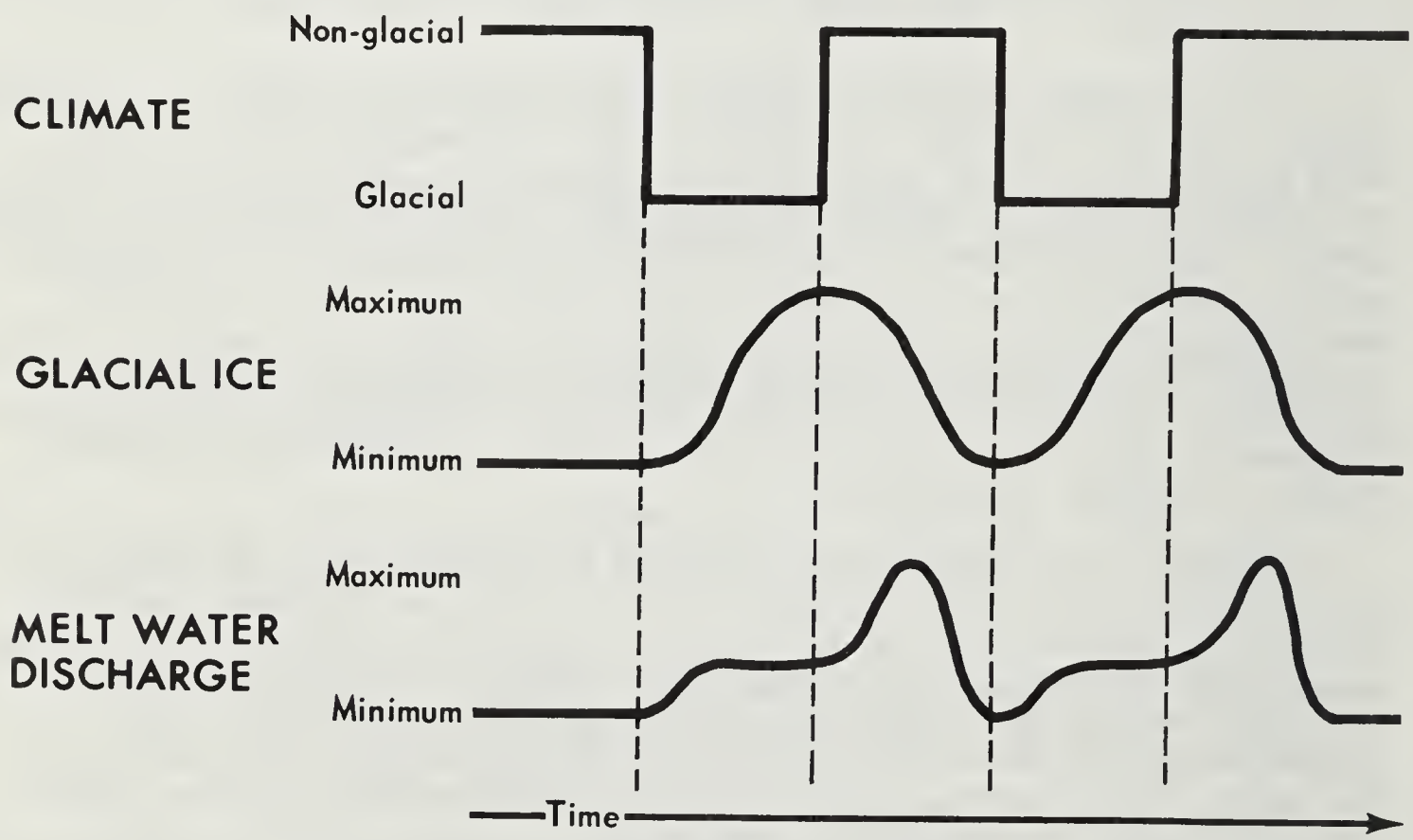

Figure 1. Schematic representation of climatic forcing and the responses of glacial ice volume (modified after Bryson and Wendland, 1967) and meltwater discharge. Note that this diagram portrays in exaggerated fashion general phase relations and does not indicate absolute magnitudes of either lag times or glacial-interglacial intervals.

Changes in glacial ice volume accompanying climatic shifts govern meltwater discharge into proglacial drainageways. Meltwater discharge, in turn, controls floodplain sedimentation and, hence, the amount of alluvium available for deflation and redeposition as loess. It follows that meltwater (and, therefore, loess) is primarily generated following a shift from glacial to non-glacial climate.

In contrast to the abrupt glacial climatic transition, the concurent response of glacial ice volume is gradual. In fact, the time constant of glaciers is considerably longer than that of atmospheric circulation patterns, so that the growth-decay of glaciers approximates a normal curve (Figure 1). During a glacial climatic episode, it simply takes time for glacial ice to accumulate to a volume that is in equilibrium with the climate. Initiation of a continental ice sheet may involve either slow growth from one or more nuclear centers or "instantaneous" glacierization of a large plateau area (Ives et al., 1975). In either event, once glacial ice covers an extensive region, its preservative characteristics (e.g., high reflectivity for solar radiation) become meteorologically significant, and its growth rate accelerates. The accelerated growth rate, however, is temporary because, as the ice sheet expands into lower latitudes (altitudes), it encounters more intense radiation and higher temperatures which slow glacial growth.

After a shift from glacial climatic episode to a non-glacial climatic episode, the high albedo of the ice surface, coupled with the tremendous heat required to melt ice, retards for some time the rate of ice wastage. Then, when the thermal regime of the glacier is modified and the surface albedo drops with the wetting of the ice surface, ablation proceeds more rapidly (Pounder, 1965, p. 142-143). This ultimately leads to a melting back of the glacier to colder latitudes (altitudes) and hence, a slowing in the rate of ice wastage.

The lag time of glacier response to climatic forcing implies that great masses of glacial ice may remain long after a shift from glacial to non-glacial climate. For example, during Wisconsinan time, the last major climatic shift from glacial to non-glacial conditions occurred about 18,000 BP; yet, vestiges of Laurentide ice remained in North America until after 6,000 BP (Bryson et al., 1969). Although there were numerous reversals of this climatic amelioration, as evidenced by the deposition of more than thirty marginal moraines during this period in Illinois and Wisconsin (Frye et al., 1965), cooling episodes were short-lived, and prevailing climatic regimes favored glacial ablation.

The time lag of glacier response to climatic forcing also suggests that meltwater discharge peaks sometime after a major glacial to non-glacial climatic shift (Figure 1). This interpretation is confirmed for the late Wisconsinan disintegration of Laurentide ice by oxygen isotopic analysis of planktonic foraminiferans in deep-sea cores from the Gulf of Mexico (Kennett and Shackleton, 1975). These studies indicate that influx of meltwater reached dramatic proportions by 15,000 BP--three thousand years after the onset of climatic amelioration. The flow of meltwater into the Gulf of Mexico tapered off rapidly after 13,500 BP, when the principal drainage shifted away from the Mississippi River to the St. Lawrence. Furthermore, the most rapid rate of eustatic sea-

level rise apparently began thousands of years after 18,000 BP, reflecting a delay in the major period of meltwater generation (Walcott, 1975).

Regardless of climate, as long as there was glacial ice on the North American continent, there was some seasonal ablation. Hence, proglacial floodplain deposition and some loess generation occurred during both glacial and non-glacial climatic episodes. This is confirmed, for example, by the ^{14}C dates of late Wisconsinan Peorian loess in Illinois, which range from 20,300 BP to 13,700 BP (Willman and Frye, 1970). If, however, meltwater discharge is a reasonable indicator of the volume of sediment available for loess generation, then the bulk of loess deposition took place during non-glacial climatic episodes; long after the shift from glacial to non-glacial climate.

Assignment of peak loess deposition to periods of non-glacial climate is compatible with the faunal content of late Wisconsinan loess. For example, in Illinois, Frye and Willman (1958) report abundant terrestrial snails in Peorian loess--in some cases within fifteen kilometers of the former glacier margin.

PALEOCLIMATIC IMPLICATIONS

Certain physical properties of loess units may be examined to reconstruct the character of depositional winds (Handy, 1976). If the bulk of loess deposition occurred during non-glacial climatic episodes, then the inferred winds are components of non-glacial atmospheric circulation patterns. Further, the seasonal nature of loess deposition is tied to an annual glacial ablation cycle. In winter, ablation was minimal and frozen soil and snowcover shielded floodplains from eolian activity. With the onset of spring and continuing through the summer, ablation was vigorous and proglacial rivers and streams overflowed their banks, depositing alluvium on their floodplains. As temperatures began to fall during late summer and early autumn, ablation waned and the rivers withdrew to their channels, thus exposing fresh silt deposits to dessication and wind erosion. Hence, in those regions where floodplains served as the major source of silt, it is likely that loess was deposited primarily by autumnal winds.

SUMMARY

In the Central United States, loess owes its origin primarily to wind erosion of glacial outwash floodplain deposits. Hence, loess is intimately associated in time and place with continental glaciation. Because generation of meltwater is a key requisite to floodplain deposition, however, it is likely that loess was generated primarily during non-glacial climatic episodes. Further, it is likely that the bulk of loess was deposited long after the glacial to non-glacial climatic shift and that loess was deposited primarily by autumnal winds.

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DISTRIBUTION OF *HYDROPSYCHE* AND *CHEUMATOPSYCHE* (TRICHOPTERA: HYDROPSYCHIDAE) IN RELATION TO THE THICKNESS OF AN ALGAL MAT

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ABSTRACT

The number of caddisfly larvae in the Fox River, Illinois, were found to decrease as the thickness of an algal mat decreased. The mat apparently provides support for larval retreats and possibly increased food availability. Algal mat thickness was postulated as a means of estimating caddisfly populations.

INTRODUCTION

The relationship between benthic invertebrates and plant detritus has recieved considerable attention. Egglishaw (1964) found 70 per cent of the river invertebrate fauna associated with plant detritus. Recently numerous investigators have associated the type and amount of detritus with the feeding activity of various macroinvertebrates (Fahy, 1972; Cummins et al., 1973; MacKay and Kalff, 1973; Wallace, 1975a). Many of these researchers, as well as Cummins (1964) and Wallace (1975b), have indicated that trichopteran presence and abundance may be related to detritus both as a source of food and for material for construction and attachment of larval retreats. These investigations have delt with detritus which usually collects in protected areas behind or under rocks or other debris, however, the Fox River, Illinois, has a thick layer of alga-bound detrital debris on the substrate below flood control weirs. In this study we investigated the occurrence of two genera of Hydropsychidae in relation to the quantity, as measured by thickness, of the algal mat.

STUDY SITE AND METHODS

Seven sites were sampled including, from the northern-most site to the mouth of the river: Waterford, Wisconsin, and Algonquin, Elgin, South Elgin, Geneva, Montgomery, and Dayton, Illinois. Samples were

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taken from late June to early August of 1973 and 1974. Since emergence of most Hydropsychidae reported from the Fox River takes place from April to September (Ross, 1944) the caddisfly larval population included both early and late instars. All sampling sites were in the riffle-rapid areas below small flood control weirs located in the previously mentioned cities. Samples were taken in 40 to 60 cm of water. Water chemistry of the sites was similar. The substrate was predominantly gravel with small rocks. A minimum of five samples were taken at each sampling site with a 0.1 m^2 Surber net. The net was used as a gathering devise with all the substrate to a minimum depth of 6 cm collected in the net. The substrate and debris were then placed in plastic trays and covered with water. After the collected material was allowed to stand in the trays for 30 minutes, which resulted in the movement of the larvae out of their retreats since there was no current, the rocks and large pieces of gravel were scraped. A flotation technique described by Anderson (1959) using a sucrose solution with a specific gravity of 1.12 was used to collect the caddisfly larvae. The larvae were identified, counted, and the number per meter squared determined for each sample and site. Ten measurements of the algal mat were taken at each sampling site in a transect, 10 meters from the dam face, across the section of the river bottom which was always under water and approximately in the same area where the Surber samples were taken. The thickness of the algal mat was measured by inserting a metal ruler through the mat to the surface of a rock or to the gravel substrate and the depth of the mat surface marked with a moveable marker on the ruler.

RESULTS AND DISCUSSION

The algal mat was composed of small pieces of plant debris, primarily deciduous tree leaves and twigs, and sand which had collected in the filamentous algae *Cladophora*. It has been referred to as an algal mat in this paper since the basis for its formation was the *Cladophora* and it occurs on substrate subjected to currents. The caddisflies incorporated this material into their net-spun larval retreats. The densities of caddisfly larvae were the highest where the mat was the thickest, Table 1. The activity of larval retreat and pupal case construction would tend to aid in the process, along with the *Cladophora*, of binding the detrital material and sand into a thick mat on the substrate surface. As indicated by the high correlation coefficients, r values in Figure 1, this was particularly advantageous to *Hydropsyche* which have been found to construct their retreats and straining nets on the top of rocks (Wallace, 1975a). Thus through the support provided by the mat this caddisfly was able to construct its collection nets in areas where the current would carry more material into the nets. Some grazing on the *Cladophora* may also have occurred. Where algae were not available for the formation of a mat or as a food source, caddisfly larvae were not abundant. It was also noted that the composition of the caddisfly population changed as the mat depth decreased, *Cheumatopsyche* dominated the sites where little or no mat occurred, Table 1.

The regression analysis of algal mat thickness and caddisfly larval numbers showed a positive relationship between the numbers and

Table 1. Number of caddisfly larvae and thickness of the algal mat at each of the sampling sites, plus or minus one standard deviation. The sites are listed in order from the northern most site to the mouth of the Fox River.

Sampling Sites	No. of Surber Net Samples	Total Caddisfly Larvae per m^2	±	*Hydropsyche* Larvae per m^2	±	*Cheumatopsyche* Larvae per m^2	±	Algal Mat Thickness mm	±
Waterford	5	11024	652	6021	226	5003	630	5	1.3
Algonquin	8	18124	1648	11894	467	6230	394	30	4.2
Elgin	6	4935	287	2037	375	2898	125	8	2.1
South Elgin	8	13555	771	10315	411	3240	244	22	3.5
Geneva	8	15464	1082	13806	687	1658	384	26	6.3
Montgomery	5	2223	314	740	108	1483	262	1	0.8
Dayton	5	836	141	45	6	791	137	trace	

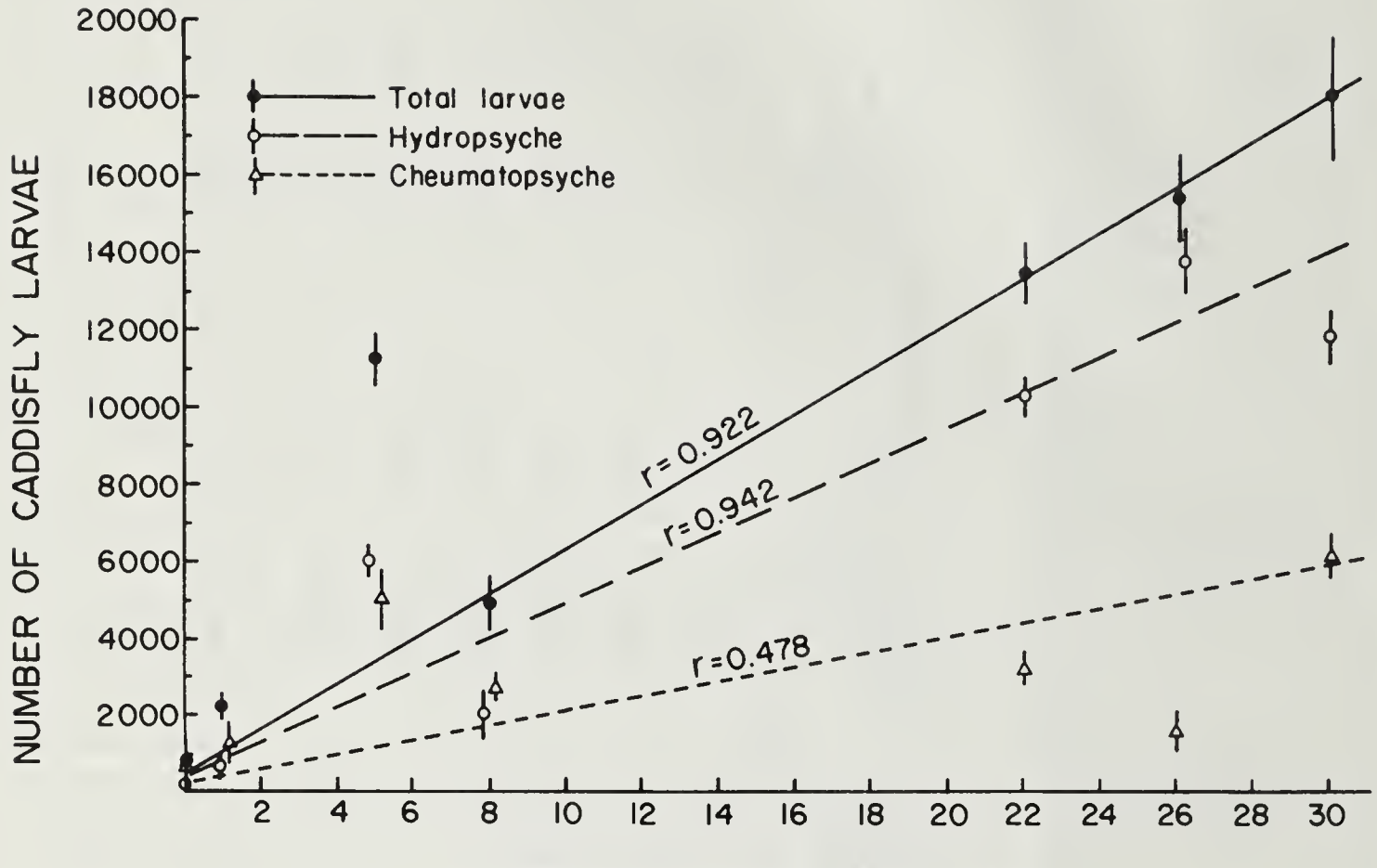

Figure 1. Regression analysis of algal mat thickness verses number of caddisfly larvae per meter squared of river bottom. The bars at each point represent one standard deviation and points are means of from 5 to 8 Surber sampler and 10 mat thicknesses.

mat thickness for *Hydropsyche*, *Cheumatopsyche*, and the total caddisfly cummunity. As in Figure 1, the strongest positive relationship was for total larval numbers and *Hydropsyche* numbers. *Cheumatopsyche* only had an r of 0.478 but the relationship was positive. Therefore, it may be possible to use mat thickness as an estimate of caddisfly larval numbers particularly for *Hydropsyche* and or the total caddisfly population. Application to other river systems will require further testing.

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THE OCCURRENCE OF *BANGIA ATROPURPUREA* (ROTH) C. AG. (RHODOPHYCEAE) IN ILLINOIS WATERS OF LAKE MICHIGAN

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ABSTRACT

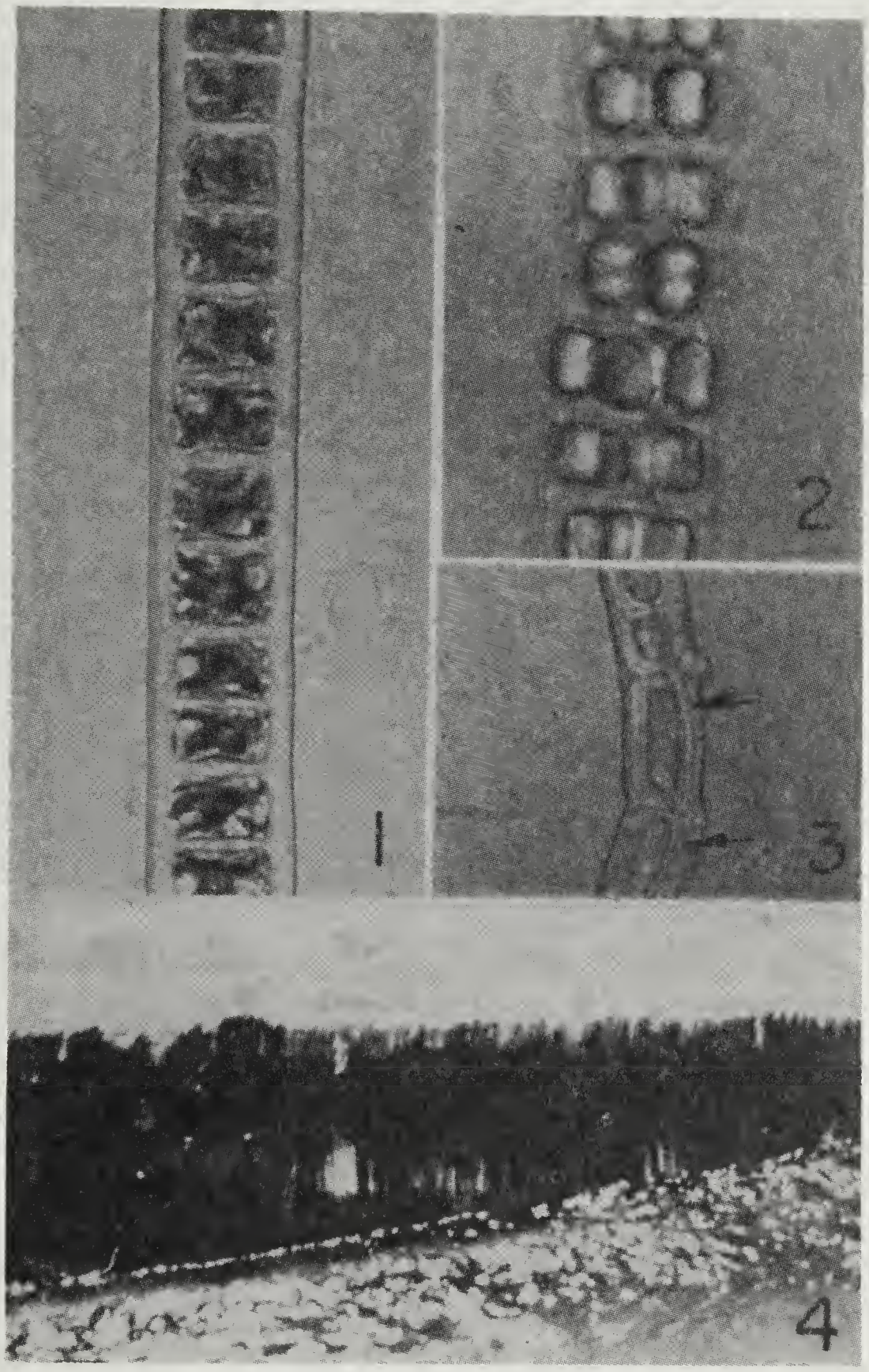
The freshwater red alga, *Bangia atropurpurea* (Roth) C. Ag. is reported for the first time in Illinois. Initial specimens were identified in collections from Lake Michigan at Lake Forest, Lake County, in October, 1975; an earlier unpublished record obtained on June 15, 1968, is also noted. Additional distribution records are reported.

Bangia atropurpurea (Roth) C. Ag., a well-known freshwater red alga, was discovered in a sample of *Cladophora glomerata* (L.) Kutz. obtained from a shoreline area of Lake Michigan at Lake Forest (Lake County, Illinois) in October, 1975. Although collections from this location had been made on many previous occasions, this was the first time that the existence of the red alga became apparent. While the presence of this alga in Illinois waters of Lake Michigan has been known since 1968 (Ponce de Leon, personal communication), the author believes this account to represent the first published report for *Bangia* in Illinois.

Since our first encounter with this alga in 1975, subsequent collections have confirmed its establishment from the Wisconsin-Illinois line in northeastern Lake County to as far south as northern Cook County. In addition to the Lake Forest record, the occurrence of *Bangia* has now been confirmed at the following locations: Spring Bluff Forest Preserve near Winthrop Harbor, Illinois Beach State Park near Zion, North Beach in Waukegan, Center Park in Highland Park, Tower Road Beach in Winnetka, Lookout Lighthouse Park in Evanston, and adjacent to Montrose Harbor in Chicago.

Credit for the first collection of *Bangia* in Lake Michigan belongs to Maxine C. Long who collected specimens on June 15, 1968, in the vicinity of the Forty-ninth Street Beach in Chicago (Ponce de Leon, personal communication). These specimens are deposited in the cryptogamic collection of the Field Museum of Natural History in Chicago.

It is now apparent that the alga has become generally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established in the southern end of Lake Michigan. Recent surveys by Stoermer and Bowman (personal communication) have established its occurrence along the eastern shore in both Michigan and Indiana, while Blum (personal communication) reports its widespread development in the vicinity of Milwaukee, Wisconsin, and adjacent shorelines.

At all Illinois locations examined in 1976 the alga formed extensive, smooth coatings on a variety of firm substrates: rock, concrete, wood, and steel such as found in piers, jetties, seawalls, etc. As a rule, it grew in close association with Cladophora, but, unlike the latter plants, tended to become established in a clearly defined supralittoral band. Bangia appeared to be second in abundance only to Cladophora at each location visited.

In form and habit, Illinois specimens conform to usual descriptions of the taxon (Smith, 1950). Typical plants are unbranched, up to two centimeters or more in length and basally attached. Each cell in the thallus has a large, stellate, reddish-brown plastid containing a central pyrenoid; pit connections between adjacent cells are lacking. Younger portions of the thallus are uniseriate (Fig. 1), while older portions become multiseriate through repeated periclinal divisions (Fig. 2). Cells near the basal portion of the thallus typically produce slender, basally directed, rhizoid-like extensions that provide additional anchorage for the plants (Fig. 3). The appearance of the plants is further characterized through the presence of firm, hyaline sheaths which surround individual as well as all cells of the filament (Fig. 1).

Although Bangia has an attached habit, free filaments were often found intertwined among filaments of Cladophora. Kishler and Taft (1970) reported a similar association between these plants in Lake Erie. Like Cladophora, Bangia appears to attain best development where sunlight is plentiful and agitation by water frequent.

In 1976, peak development of Bangia at Lake Forest appeared

Figure 1. Uniseriate portion of B. atropurpurea that reveals stellate plastids and sheaths surrounding both individual cells and entire filament, X 2,300.

Figure 2. Multiseriate condition resulting from repeated periclinal division of cells in older filament of B. atropurpurea (preserved), X 4,300.

Figure 3. Rhizoid-like extensions (arrows) from basal cells in holdfast region of B. atropurpurea (preserved), X 2,300.

Figure 4. Supralittoral band of B. atropurpurea and Ulothrix zonata growing above submerged Cladophora glomerata on concrete jetty at Lake Forest, July, 1976.

to be reached in July. During this period, a rich reddish-brown band several centimeters in height became apparent on vertical surfaces above the coarser and much bushier growth of Cladophora (Fig. 4). Ulothrix zonata (Weber and Mohr) Kützing was a third major component of this association. By late summer the red alga had begun to decline and by early November the plants, en masse, were buff-colored and only weakly tinged with pink.

According to Geesink (1973), freshwater Bangia does not produce a Conchocelis phase during its life history and the only known means of reproduction is by neutral spores. Because he found that B. fuscopurpurea (Dillw.) Lyngb. could successfully adapt to fresh water and conversely, B. atropurpurea (Roth) C. Ag. to seawater, he concluded that the species were conspecific and that the latter binomial took precedence. Geesink clearly demonstrated that adaptation takes place through neutral spore formation. Such evidence lends support to the suggestion of Kishler and Taft (1970) that Bangia was introduced to the Great Lakes via ocean-going vessels plying the St. Lawrence Seaway.

ACKNOWLEDGEMENTS

The author wishes to express his appreciation to Professor Clarence E. Taft for assistance in locating sources of some early collections of B. atropurpurea in Lake Michigan; to Professor John L. Blum for information on the distribution of the alga in Wisconsin and the source of the first collection in Lake Michigan; to Dr. Ponce de Leon of the Field Museum of Natural History for information on the first collection in Illinois waters of Lake Michigan; to Luanne C. Frey and Beth Bowman of the Great Lakes Research Division of the University of Michigan for providing information on the distribution of the alga along the eastern shores of Lake Michigan; to Nancy Leavitt and Steve Spangler for supplying some of the collections; to Debbie Marlewski for calling to his attention specimens initially identified at Lake Forest; and to John Keller for supplying the photograph used in Fig. 4. The author is also grateful to Lake Forest College for providing support for publication of the manuscript.

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CURRENT STATUS OF *AGASSIZOCRINUS HEMISPHERICUS* WORTHEN FROM RANDOLPH COUNTY, ILLINOIS

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ABSTRACT

A hypotype specimen is recorded from the Menard Formation, Elviran Stage, Chesterian of Randolph County, Illinois and the species referred to *Mantikosocrinus hemisphericus* (Worthen) in the family Cromyocrinidae. Possible affinities are discussed.

The species *Agassizocrinus hemisphericus* Worthen (1882) was described from a single specimen collected from "Chester limestone in Randolph County, Illinois." The specimen is currently housed in the Repository of the Illinois State Geological Survey, Urbana, Illinois, catalogue no. ISGS (ISM) 2451 and designated as the holotype. The only additional specimen of the species, known to this writer, has been recovered from an exposure flanking the access road to the Menard Prison Medical Facility on the west edge of Chester, Randolph County, Illinois. It is from the Menard Formation (Elviran) catalogued SUI 44065, Geology Department Repository, The University of Iowa, Iowa City. Indications are the original specimen might have come from the same horizon, probably from the old quarry at the nearby Menard State Prison. The species is very distinctive; it does not belong to the genus *Agassizocrinus*.

Wachsmuth & Springer (1886, p. 264) stated "...his [Worthen's] *A. hemisphericus*, in which the underbasals [infrabasals] do not extend beyond the column, is either *Eupachycrinus* or *Scytalocrinus*, probably the latter." The infrabasals of Worthen's specimen are damaged so that no columnar cicatrix is preserved. In the hypotype specimen the infrabasals (IBB) do extend beyond the small column scar, not that it makes any difference in generic assignment. *Eupachycrinus* has a pronounced basal concavity (downflared infrabasals) and typically *Scytalocrinus* has a shallow basal concavity so that neither genera are considered here to be closely related. Moore & Plummer (1940) listed the species as *Dicromyocrinus hemisphericus* (Worthen). Bassler & Moodey (1943, p. 291) synonymized it with *Agassizocrinus papillatus* Worthen (1882); however, *A. papillatus* is elsewhere accepted as a discrete species. Wright & Strimple (1945) assigned it as *Mooreocrinus hemisphericus* (Worthen) which assignment was followed by Webster (1973).

Infrabasals of the holotype of *hemisphericus* are damaged as noted above but the present hypotype has five discrete infrabasals which

form a planate or slightly convex base. There is no evidence of fusion or of stereom build-up such as found in the base of Agassizocrinus. Therefore, A. hemisphericus is assigned to Mantikosocrinus as Mantikosocrinus hemisphericus (Worthen), new combination, for the following reasons. Mantikosocrinus Strimple (1951) has previously been represented by a single species, M. castus Strimple (1951), type species of the genus, from the upper few feet of the Fayetteville Formation which is correlative with the lower part of the Menard Formation, according to Furnish & Saunders (1971, text-fig. 1).

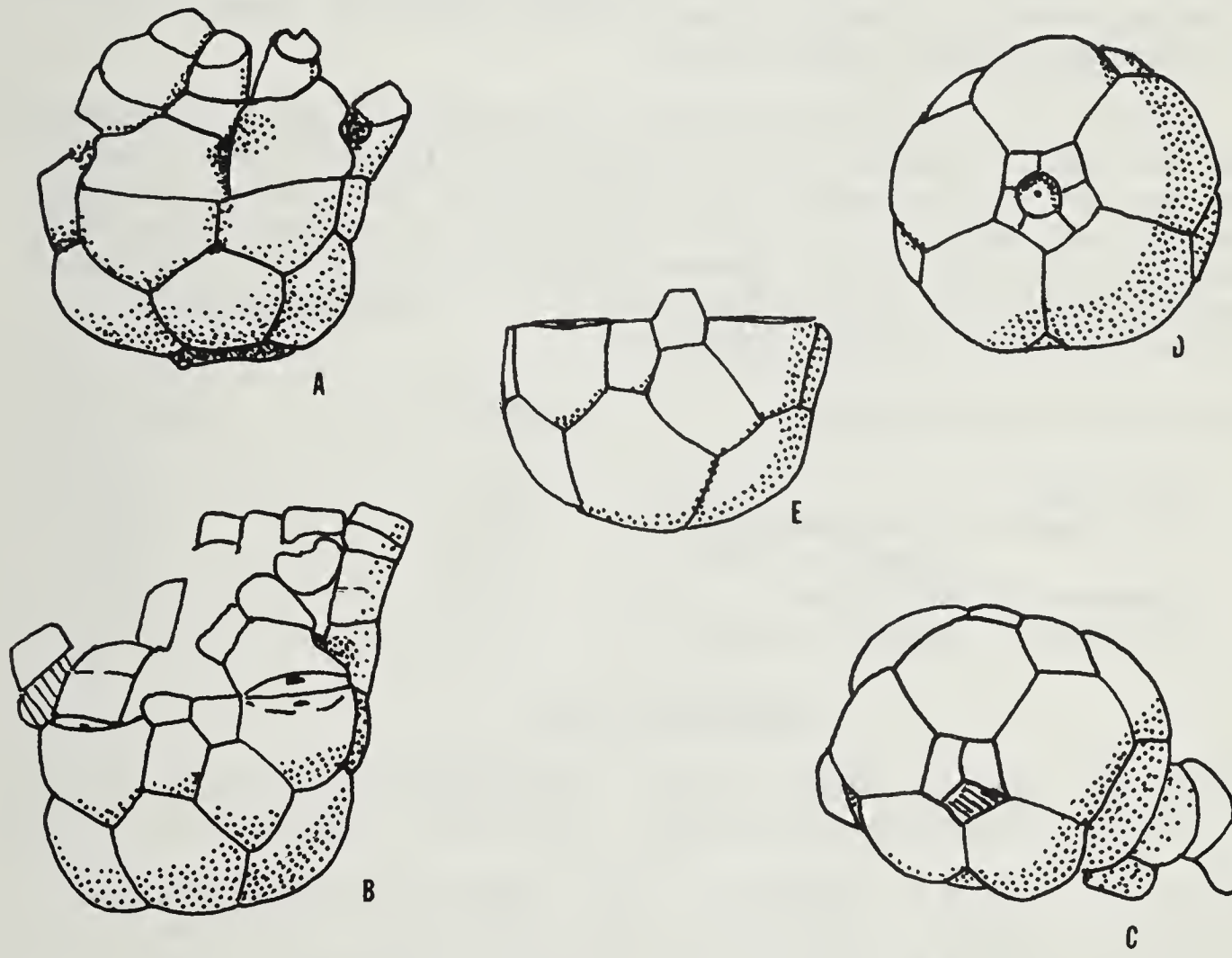

Fig. 1. Camera lucida drawings of Mantikosocrinus hemisphericus (Worthen): a, b, c, Holotype, ISGS (ISM) 2451, viewed from anterior, posterior and base; d, e, Hypotype SUI 44065, viewed from base and posterior, X6.

The cup of Mantikosocrinus castus is more globose than that of M. hemisphericus. The latter has a broad base with erect lateral sides. Individual cup plates, other than infrabasals, are more tumid in M. hemisphericus, which also has a very small columnar attachment cicatrix.

In the absence of arms positive identification at the generic level remains somewhat questionable. The cup shape and plate tumidity of M. hemisphericus is somewhat like that of Exochocrinus tumulosus (Miller),

(see Burdick & Strimple, 1969, pl. 1, fig. 7). Exochocrinus and Staphylocrinus are older (Gasperian age) but both genera exhibit fusion of the infrabasals. Staphylocrinus has thickened infrabasal plates but not much more so than other cup plates (see Burdick & Strimple, 1969, text-fig. 2, for cross section of cup). Close relationship between Mantikosocrinus and the Staphylocrinus-Exochocrinus lineage does not seem likely but it cannot be ruled out.

Mantikosocrinus is thought to be chronologically the oldest genus of the Cromyocrinidae Bather (1890), (see Moore, Lane & Strimple, 1973). It is therefore not surprising that M. hemisphericus has been assigned at various times to younger (Pennsylvanian) genera of cromyocrinids (i.e. Dicromyocrinus, Mooreocrinus).

The small size of Mantikosocrinus hemisphericus leads to speculation about the stage of growth, that is, whether it is full grown or not. There are now two specimens, found at different times and perhaps from different exposures, of the species and there are no larger specimens known with comparable gross characteristics. They are judged to be young adults because the brachials are not as elongated as might be expected were the specimens juveniles.

Measurements in millimeters:	Holotype	Hypotype
Cup height	5.3	5.7
Cup diameter (posteroanterior)	7.3	8.8
(right to left)	8.2	8.2
Diameter of IBB circlet	2.3	2.8
Diameter of columnar cicatrix	?	1.5

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CHLOROPHYLL SYNTHESIS IN THE EMBRYOS OF NELUMBO LUTEA (WILLD.) PERS.

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ABSTRACT

It has been generally believed that chlorophyll synthesis takes place in the dark in the developing embryos of Nelumbo lutea (Willd.) Pers., since mature embryos are green in color. Present experiments indicate that the maturing embryos develop green plumules in the light before they are tightly enclosed by the hardened, impervious fruit wall.

The water lotus, Nelumbo lutea (Willd.) Pers., is commonly found growing in water 2-5 dm deep throughout most of Illinois. In midsummer it produces a flat-topped conical, aggregate fruit 10-15 cm in diameter that is filled with nut-like fruits which have only a small portion of their stigmatic tip exposed. Each nut-like fruit attains a diameter of approximately 16 mm before it begins to shrink by drying to about 11 mm in diameter. These large, single-seeded fruits have been of interest to Botanists for many years since chlorophyll is present in the mature embryo. Because of the hard fruit wall it has generally been assumed that light was not necessary for the synthesis of this chlorophyll. Lyon (1902) discussed the green plumules found in Nelumbo and assumed the chlorophyll was formed in the dark. Stewart and Eyster (1939) found the green pigment to be chlorophyll b. Later, Wilson (1958) found both chlorophyll a and b present, and stated that the embryo of water lotus develops chlorophyll in the absence of light.

MATERIALS AND METHODS

Experiments to verify the necessity of light for chlorophyll synthesis in Nelumbo embryos were conducted at Lake Decatur, Macon County, Illinois, and at Lake Charleston, Coles County, Illinois, during the summers of 1959, 1967, and 1968. The study was conducted by placing maturing receptacles in darkened enclosures for a period of several weeks while the receptacles were still attached to the plants. The enclosures were made by using two different sized cans, each coated with flat black paint. The smaller can, about one liter in size, was opened at the top and had a hole in the bottom to accommodate the peduncle. A slit in the side made it possible to slip this can around the peduncle and receptacle;

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* Dr. Hiram F. Thut died on December 23, 1974. This nearly completed manuscript was recently found among some of his papers and was edited for publication by Dr. John Ebinger of Eastern Illinois University.

the slit was then covered with black friction tape. A loose fitting black cloth, fastened to the peduncle with a rubber band, was used to seal the hole around the peduncle. The second can, about three liters in size, was inverted over the smaller can. It was positioned a little higher to permit air passage into the interior of the chamber. A wooden block in the top of this outer can prevented the lifting of the receptacle into a possible lighted area. The cans were secured to stakes for support. By adding two flat metal shields or reflectors on wooden blocks above and attached to the second can, it was possible to have nearly the same temperature within the cans as the air temperature outside.

RESULTS AND DISCUSSION

To prevent light from reaching the developing embryos, 32 enclosures were set up around maturing receptacles during the first week of August in 1959, 1967, and 1968. Five enclosed receptacles were harvested in 1959 after 12 days in the dark. During this 12-day period, the developing fruits and the enclosing receptacles had attained approximately one-half size and had the yellow color of the opening flowers. When the yellow carpels were opened, the immature plumules were also yellow. The maturing fruits not so enclosed were green. Most of the receptacles were harvested after 23-34 days of enclosure and had attained their maximum size, appearing quite mature and dry. One hundred fruits husked at random from several of these dry receptacles averaged 1.06 g., while a similar lot from mature receptacles not in enclosures averaged 1.2 g. each.

The significant change, however, was in the plumule or epicotyl. Those growing in the light were green, but those maturing within the enclosures were yellow. Pigment extractions and chromatographs were made as described by Nutting, Voet, and Becker (1965); and these graphs were inspected under ultraviolet light. Two very distinct bands of chlorophyll were evident in the extractions from the plumules of fruits from the light; matching those from leaf extracts. The intense area of each band was removed as it fluoresced under ultraviolet light, and the pigment examined by a Beckman DBG spectrophotometer. The curves of absorption agree with those reported by Wilson (1958), with both chlorophyll a and b being present. However, the chromatographs of the pigments from the plumules maturing in darkness showed no chlorophylls under ultraviolet light. On removing areas identical with those showing the chlorophylls from the lighted fruits, no indication of pigments was recorded by the spectrophotometer. Thus it can be concluded that light is necessary for chlorophyll synthesis in water lotus plumules.

The dark, heavy, mature opaque walls of the dry fruits no doubt must have influenced the erroneous decision, as reported in the literature, that the plumules form chlorophyll in the dark. However, after the pigments are formed in the plumule before the fruit wall has hardened and turned dark, they may persist for years.

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AN UPPER PENNSYLVANIAN *PARACONULARIA* (COELENTERATA: CONULARIINA)

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ABSTRACT *Paraconularia kohli* Brew and Beus is reported from the Shumway limestone (Mattoon formation, Upper Pennsylvanian) of Illinois. This discovery extends the stratigraphic range of the genus from Middle Pennsylvanian (Desmoinesian) to the Missourian-Virgilian boundary in the Upper Pennsylvanian.

INTRODUCTION

Until Brew and Beus (1976) described *Paraconularia kohli* from the Naco formation (Desmoinesian) of Arizona, *Paraconularia* was only known from the Permian Period of India (Moore and Harrington, 1956) and the Mississippian Period of North America (Brew and Beus, 1976). Collections of fossil invertebrates from the Shumway limestone contain two specimens identifiable as *Paraconularia kohli*. These specimens extend the stratigraphic range of the genus in North America to the Missourian-Virgilian boundary. The present paper describes these specimens.

STRATIGRAPHY

The stratigraphic section containing the Shumway limestone at the collecting locality was described by Kosanke *et al.* (1960). Tucker (in press) listed the invertebrate fauna at this locality. Both specimens were collected from the lower bed of the Shumway limestone near the contact between the upper and lower beds of the unit. Kosanke *et al.* (1960) considered the Shumway limestone to be uppermost Missourian or lowermost Virgilian. The presence of the fusulinid genus *Triticites* supports these correlations (Kosanke *et al.*, 1960).

SYSTEMATIC PALEONTOLOGY

Family CONULARIIDAE Walcott, 1886
Subfamily PARACONULARIINAE Sinclair, 1940
Genus PARACONULARIA Sinclair, 1940
PARACONULARIA KOHLI Brew and Beus
Figure 1.

Paraconularia kohli Brew and Beus, 1976, p. 891, Pl. 1, figs. 20, 23.

Description. The straight, uniformly tapering shell has an apical angle of about 17 degrees. The faces are equal and slightly convex to flat. The mid-line is marked by a weak ridge that is more pronounced adaperturally and produces minor offsets or kinks in the transverse ribs. The interfacial corners are marked by prominent grooves. The strong

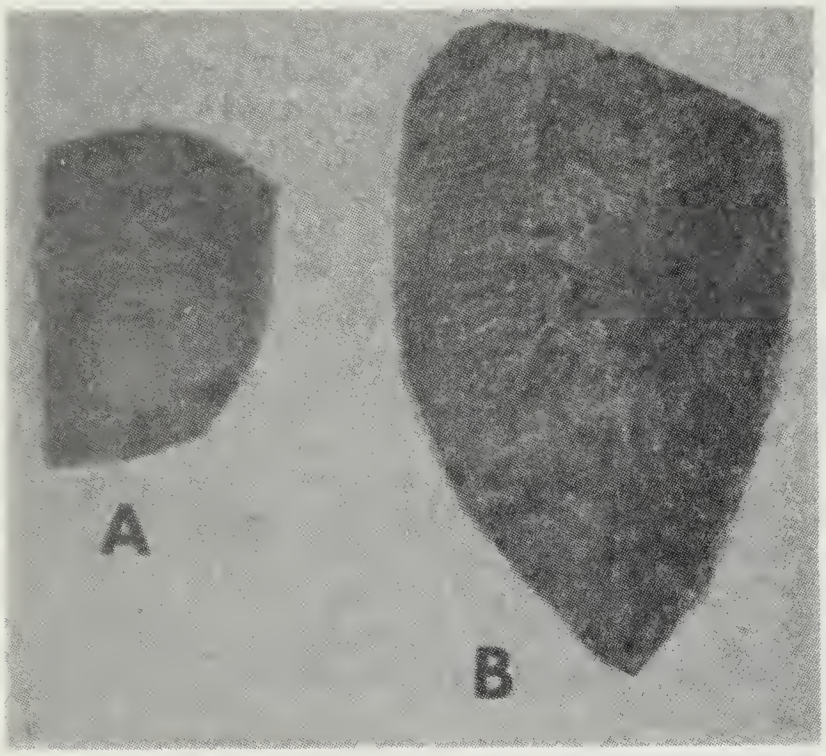

Figure 1. Paraconularia kohli Brew and Beus. A, lateral view of PE 28367; B, corner view of PE 28368. X 2.

transverse ribs which cover the shell surface do not cross the interfacial corner grooves but at their ends alternate with the rib ends from the adjacent face across the groove. In some cases the ribs abruptly bend adaperturad at the corner grooves but some of the ribs show little or no adapertural deflection. At the mid-line the ribs form adapically directed angles of about 140 degrees. The transverse ribs are faintly to moderately tuberculated on the outer surface of the shell. Inner shell layers show no signs of these tubercles which are very closely spaced. No longitudinal ribs were observed in the interspaces between the transverse ribs. Neither of the specimens are complete adapically nor adaperturally. The most complete specimen which is crushed measures 28 mm in length. The maximum facial width is 10 mm. The other specimen measures 12 mm in maximum facial width. The transverse ribs are spaced at 11 in 8 mm near the apertural end of both specimens.

Comparison. The Shumway specimens are very similar to the types of Paraconularia kohli. The only possible difference is that Brew and Beus (1976) make no mention of tubercles on the transverse ridges whereas they are present on the outer layer of the shells of the Illinois specimens. The significance of this difference is not clear. Species of Calloconularia are also superficially similar to P. kohli but all of the species of Calloconularia have longitudinal ribs in the interspaces between the transverse ribs whereas P. kohli does not.

Material. Two specimens (PE 28367; PE 28368) are deposited in the collections of the Field Museum of Natural History, Chicago.

Occurrence. Paraconularia kohli is known from the Naco formation on Kohl Ranch in Arizona (Brew and Beus, 1976) and from the Shumway limestone at SE ¼, SE ¼, SW ¼, sec. 26, T9N, R5E, Effingham Quadrangle, Effingham County, Ill.

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